PUBLIC HEALTH.

REPORTS

OF

THE MEDICAL OFFICER OF THE PRIVY COUNCIL AND LOCAL GOVERNMENT BOARD.

NEW SERIES, No. I.

ANNUAL REPORT TO THE LOCAL GOVERNMENT BOARD WITH REGARD TO THE YEAR 1873, WITH APPENDIX.

Presented pursuant to Act of Parliament.

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REPORT.

TO THE RIGHT HONOURABLE THE PRESIDENT OF THE LOCAL GOVERNMENT BOARD,
&c. &c. &c.

SIR,

As the officer appointed to make report to the Local Government Board, for the annual information of Parliament, in relation to matters concerning the Public Health, and to the inquiries and other proceedings which the Board, under the Public Health Act, 1858, may have directed in such matters, I beg leave to submit to you that for the past two and a half years, and particularly during the last year, the circumstances of official and administrative transition, consequent on the Acts of Parliament of 1871 and 1872, have been such that no consistent scheme of report in general relation to the sanitary interests which are under the Board's superintendence has been possible to me; and the present Report, which regards the year 1873, must necessarily, even more than its two predecessors, illustrate the difficulty of the unsettled circumstances.

2. Of the Board's business during the year 1873 in matters of concern to the Public Health, the largest and incomparably the most important part was that which related to the action of local sanitary authorities under the Act of 1872 in appointing their Officers of Health and Inspectors of Nuisances. This action, which the Legislature, at the instance of the Royal Sanitary Commission, had made obligatory on all the local authorities, and which included as its most important feature that for the first time the Medical Profession throughout the country was to be brought into official use with a view to the better prevention of disease, was, at least in part, even in the terms of the statute, tentative*; and evidently the discretion to be used by each authority in its compliance with the terms of the law would, for better or worse, be of great future consequence to the local working of the Sanitary Acts, and to eventual public estimation of the new machinery. The Board throughout the year 1873 was advising local authorities in detail on particular schemes of appointment and duty for

* In regard of rural sanitary districts the first appointments of medical officers of Health and Inspectors of Nuisances under the Act must be for a period not exceeding 5 years.

the above-mentioned sanitary offices; but this branch of business was exclusively in the hands of the non-medical officers of the Board, and I therefore do not here attempt to give any account of the proceedings or their results.

3. Of the medical inspections which were made during 1873 in regard of local sanitary questions, and which under the peculiar circumstances of the year were but 42 in number, I subjoin a detailed list. See Appendix, No. 1. In one of them the inspection related to a question of hospital-accommodation, and in one to certain manufacturing processes causing nuisance to several districts; but otherwise universally the ground of inquiry was some more or less important presence of disease; and the last column of the subjoined table will enable some judgment to be formed as to the extent to which the powers of the authorities had been exercised, and the duties fulfilled, in the particular instances referred to. I may add that, as some of these local inquiries were in cases of much sanitary interest, I propose bringing their results before you, as soon as practicable, in a separate supplementary report.

4. One considerable inquiry, of a sort different from the above, was in progress during part of the year, but has not hitherto been completed. It has in view to examine the sanitary conditions under which certain industries are now carried on, as compared with the lung-diseasing conditions which existed in 1860–64, when special report on them was made to the Privy Council; and I have to state that during 1873 contributions towards the making of that comparison were furnished in inquiries of the Medical Department as follows: by Dr. Ballard in respect of metal trades at Sheffield, Wolverhampton, Alcester, Bromsgrove, and Birmingham; by Dr. Blaxall in respect of glove-making at Yeovil; by Dr. E. Smith in respect of tailoring and printing in London; by Dr. Thorne in respect of pillow-lace manufacture at Newport and Towcester, of machine-lace and hosiery manufacture at Nottingham, Radford, and Basford, of straw-plaiting at Tring and Berkhampstead, of silk-weaving at Leek, of silk-weaving and watch-making at Coventry, and of hosiery manufacture at Leicester and Hinckley.

5. The business of the Board as to vaccination in 1873 regarded, as usual, the following matters:—(*a*) the proceedings of local authorities and officers under the Vaccination Acts; (*b*) the provisions by which the national supply of vaccine lymph is maintained; and (*c*) the arrangements which give effect to the Order of Council regulating the qualifications of public vaccinators. (*a*) In superintendence of local proceedings under the Vaccination Acts, the Medical Department inspected 1,617 vaccination-districts in 354 Unions or parishes: each district-inspection involving, first, an inquiry into the state of vaccination in the district; secondly,

where requisite, a notification to the authority as to defects found in the local administration of the Acts, with advice as to the changes required; and thirdly, in suitable cases, a recommendation of the vaccinator for pecuniary award, under section 5 of the Vaccination Act, 1867, out of moneys voted by Parliament for the purpose, and of which in 1873 an amount of 8,508*l*. 17*s*. 4*d*. was thus distributed. Particulars of the vaccination-inspections of 1873, and of the awards made to public vaccinators, are subjoined in Appendix, No. 2. (*b*) Acting as National Vaccine Establishment, the Medical Department supplied vaccine lymph in answer to 9,569 applications. Particulars as to the sources whence this lymph was derived, and as to the applicants who received it, are given, with other statistics of the National Vaccine Establishment, in Appendix, No. 3. The stations supplying lymph for the public service were as usual specially inspected. (*c*) The several educational vaccinating stations, established with reference to the Order of Council which regulates the qualifications of public vaccinators, require in this relation to be inspected on behalf of the Board, and were, as usual, so inspected in 1873; but as they are for the most part stations which also supply lymph for the public service, and as the efficiency of a station for the latter purpose greatly concerns its efficiency for the former, the inspection of them in the one relation conveniently combines with inspection of them in the other, and in practice the two objects are attained in single inspections.

6. Lastly, I have to report that in 1873, and particularly during much of the second half of the year, Asiatic cholera was more or less prevalent in many parts of continental Europe, and sometimes—as at Paris, Havre, Rotterdam and Antwerp—in places which have constant and easy communication with England. In our relations to cholera on the continent of Europe there are at present some points of interest on which I may have occasion to submit to you a supplementary report: but I need not here do more than refer to the Board's actual proceedings as to cholera during the year on which I am reporting. In July 1873, in view of the then circumstances, the Board issued (instead of an Order which had been issued in 1871 by the Lords of the Council) an amended Order, prescribing rules for the detention and examination of ships suspected of choleraic infection, and for dealing with cases of actual infection. See Appendix, No. 4. The Board also circulated among the local sanitary authorities of England a Memorandum (App., No. 5.) which at the Board's desire I had prepared, on the precautions generally proper for local adoption under the circumstances; and particular communications on the subject of local arrangements were also had by the Board with several of the sanitary authorities of ports. In a few cases, namely, three times in the Thames, twice at Liverpool, once at Southampton, and at least once at Swansea, the local arrangements were tested by infectious arrivals; and in most of these cases, as well as in several instances of false alarm, local inquiry

was made by inspectors from the Medical Department: Dr. Buchanan, Mr. Radcliffe, Dr. Gwynne Harries and Mr. Power.*

The above account refers, as I have stated, to a period of official and administrative transition, during which it is impossible to represent the Local Government Board as directing inquiries under the Public Health Act, 1858, in any definite relation to the new sanitary system of the country: but with the end of the year 1873, that period of transition may be deemed to have nearly accomplished itself; and I may hope that, before the next season arrives for the submission of the Annual Report under the Act of 1858, it may have become possible to begin in a really useful sense such new succession of reports as the changed conditions of sanitary administration seem henceforth to require.

If, in that hope, I may venture to indicate from beforehand the purposes which it seems to me the reports under the Act of 1858 must in future be expected distinctively to fulfil, I would say that, whatever else they may be expected to do, at least they must be expected to set forth the knowledge which the Board, through its department of sanitary inquiry, obtains, with regard to the *practical effect of the laws which are in force for the prevention of disease throughout England.* It is the common conviction of persons who have most studied the subject, that the deaths which occur in this country (now about half a million a year) are by fully a third part more numerous than they would

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* In one case, among those which particularly concerned London, the danger was extremely great. On the 28th July, a ship from Hamburg landed at Blackwall a body of 82 Danish and Swedish emigrants, in destination for New Zealand. During the voyage no sort of illness, except sea-sickness, had been noted among them, and therefore no objection to their landing had been raised under the Board's recent Order; but almost immediately afterwards, when, to await re-shipment, they had settled themselves in various lodging-houses in Whitechapel, and were legally in the position of ordinary residents in London, it become evident that cholera was among them; and the Board's first information of this state of the case was due to the courtesy of a private medical practitioner who had been called to the sick. As soon as his letter was received by the Board, communication on the subject was had by the Medical Department with the authorities and others who were concerned, and by great exertions of all, under a state of law in which everything depended on voluntary exertions on one side and absence of objection on the other, the emigrants by 31st July (the day on which they were to have been re-shipped for New Zealand) were collected and placed in isolation on the port-authority's hospital-ship "Rhin," off Gravesend, to remain there under medical care. Then the houses where they had been temporarily lodged, and which meanwhile had been under close observation by the Whitechapel officer of health, Mr. Liddle, were finally disinfected. Of the 82 emigrants, 28 sickened and 8 died; but to our own population there was no extension of the disease. The removal was managed by the emigration agent, to whom the great importance had been explained of getting all the emigrants together into suitable quarters where their state of health could be medically watched and cases of incipient cholera be isolated; but this action, taken by him with the co-operation of the recently appointed able health-officer of the port, Mr. Harry Leach, was without any support from law. That he was able to do as advised, and to do it in such a way as to transfer an immense danger from the heart of London to a comparatively safe distance, was due to the goodwill of the port-authority, who made their Gravesend ship available for the relief of Whitechapel; and it seems to me that by acting in that liberal spirit the Corporation of the City helped London out of a serious difficulty. Dr. Buchanan, assisted in part by Dr. Gwynne Harries, was the inspector who visited in this important case.

be if existing knowledge of the chief causes of disease were reasonably well applied throughout the country; and I need hardly add that, if thus some 125,000 cases of preventable suffering annually attain their final record in the death-register, that vast annual total has the terrible further meaning that each unit in it represents an indefinite (often very large) other number of cases, in which preventable disease, not ended in death, though often of far-reaching ill-effects on life, has also during the year been suffered. The Local Government Board, viewed as a Central Board of Health, and the more than fifteen hundred District-Authorities which, each with its appointed Medical Officer of Health, locally administer the health-laws, may be regarded as having had their respective functions assigned to them in special and systematic relation to that state of things; and it will be peculiarly with regard to that relation, namely, as rendering account of the central share of the responsibility, that the future Annual Reports of the holder of my office will, I apprehend, have their essential meaning.

In the sanitary administration of England, there are certain prescribed cases (chiefly in regard of local powers of rating, mortgaging, and bye-law making) where the local action cannot be taken without previous express approval of the Central Authority; and no doubt the central authority, in its exercise of that responsibility, has often been able to influence very advantageously the course which Local Authorities have proposed to take. Also it possesses, in supposed reserve for great epidemic emergencies, a power to issue directions for certain purposes under the Diseases Prevention Act, 1855. But with exception of such special cases, the function of the Central Authority in regard of local sanitary action is primarily one of mere observation and inquiry. Not itself authorised to interfere in such action except where the results are at fault, it watches and interrogates results; and it is distinctively in this relation to the sanitary interests of the country that the Local Government Board will be represented by its ordinary proceedings under the Public Health Act, 1858. For the eventual test of local sanitary administration will be the success with which it prevents disease; and, in each case where the preventable disease is not prevented, the Local Government Board can, by skilled inspection under the Public Health Act, 1858, satisfy itself as to the circumstances and causes of the failure: giving thereupon such skilled advice, or proceeding in certain extreme cases to issue (under § 49 of the Act of 1866 or under the Diseases Prevention Act) such orders and directions, as the particular occasion may require.

What standards of success in Disease-Prevention ought to be taken as satisfactory by the local authorities which now have to act in that matter, and by the central authority which has to superintend their action, is a question on which I need not here submit more than very few general observations. Our large annual total of preventable deaths receives probably from most or all of the fifteen hundred sanitary districts of the country

contributions, larger or smaller, which in their respective degrees are evidences of sanitary unsuccess; and I would therefore point out, as of very important bearing on the whole tone of sanitary administration, that, in the death-accounts which have henceforth to be critically examined by both Central and Local Authorities, figures which arithmetically make but little show may, for administrative purposes, have immense meaning. One or two deaths by enteric fever, noted in a Quarterly Return of the Registrar-General in regard of some village or small country town, may in hundreds of instances correspond to long-continued local conditions of scandalous filth and unwholesomeness: one or two deaths by scarlatina or small-pox, almost unnoted in regard of some considerable town, may represent the beginning of what, three months later, will be a terrible epidemic, agitating the community with distress and fear, and adding prodigiously to the whole year's death-rate of the place; and it is with reference to considerations like these, that records of even single deaths will now have to be medically read and interpreted. In regard of such epidemic visitations as are aptest in this country to excite local alarm, and to be felt as conclusive appeals for central interference, it may appear a mere truism to say that, in proportion as the disease is present, the time for preventing it is past: but for practical purposes it is indeed all-important to remember that sanitary administration has its hopes of success in preventing, not in arresting, great epidemics; and that, if warnings are not taken from the smaller excesses of disease, catastrophes, not further warnings, may be next to come. It seems almost unnecessary to add that a method of procedure which waits for death as its ground of action may peculiarly dispense with cumulative proofs; and that, as no one preventable death can any longer be remedied in regard of him who has suffered it, so the record of it may the more emphatically claim to be read as a protest on behalf of others.

The vigilance which the Local Government Board has to exercise in regard of the local prevention of disease in England will of course not universally need to express itself in the form of inspections. As regards the Board's giving of advice or assistance to local sanitary authorities and their officers, clearly this would be limited, first, by the fact that, unasked, it could not properly have place except where the local results showed need for it; and secondly, by the consideration, that, in the large and permanent interests of sanitary government, a maximum of local self-reliance and a minimum of central intervention are in themselves important aims. And even as regards mere inquiry into the facts of what is locally going on, correspondence (often bringing in the reports of local officers) will in some cases afford the Board all adequate information for its purpose.

On the other hand, and provided due regard be had to the above considerations, the advantage which may be gained to the sanitary progress of the country by inspections conducted, at least for many years, on a sufficiently large scale, under the Public Health Act, 1858, can hardly, I think, be over-estimated. It

has, I believe, been the experience of the Local Government Board in those branches of its administration which do not concern the public health (as particularly in its poor-law and common municipal business) that the personal agency of Inspectors of the Board, as distinguished from mere inquiry and advice by letter, is, in a very large proportion of cases, essential to the success of the work: first, in order that the Board may competently understand the local conditions or proceedings which it desires to judge; and secondly, in order that, in a degree and with an effect which no letter-writing can attain, it may make to the local authorities with which it has concern precisely such representations, and may give them precisely such advice, as the particular local circumstances require. The Board would probably not expect experience of a different kind in its future, essentially medical, province of sanitary superintendence; and indeed, as regards this province, my own experience enables me to say with certainty that it is peculiarly one in which clerical, as compared with inspectorial agency, would show itself inadequate to the purpose. By skilled inspections under the Public Health Act, 1858, on such a scale as practically to represent a central audit of local death-accounts, and an exertion of central influence or authority in favour of more active or better-directed local efforts in places where human life had not been sufficiently cared for, the Local Government Board would be in reality, though only in the limited sense which the law prescribes, a Board of Sanitary Superintendence for England.

Briefly then, as regards the Annual Reports to be hereafter made under the Public Health Act, 1858, the state of the case, as I apprehend it, will be this. The Local Government Board will from time to time determine what degree of central vigilance as to the local prevention of disease shall be represented by its proceedings under the Act, and will regulate in accordance with such standard of work the staff by which the work has to be executed. It will be for the holder of my office annually to lay before the Board a report of the proceedings so taken: substantially a report on the new sanitary administration of the country, as examined by the Board from the standpoint of results; and which, so far as means for it exist, would aim at exhibiting, for the information of Parliament, what, year by year, are the chief existing excesses of disease in the several sanitary divisions of England, and what the relation of such excesses to insufficiencies of law or administration. Incidentally to the above, which I have regarded as the essential business of future annual reports under the Act, it would probably be of advantage to the public service that the reporter should use the same annual opportunity for submitting to the Board, with a view to publication, such new knowledge as the Medical Department might during the past year have acquired with reference to the prevention of disease, and such new memoranda of advice on sanitary subjects as the growing experience of the Department might be held to justify.

From among the many points of local relation which the Board's sanitary superintendence must include, there is one which in con-

clusion I will specially mention: not indeed without confessing that, in love and honour for my own profession, I regard it with warm personal interest; but believing that I may, nevertheless, without partiality describe it as of fundamental interest to the working of the scheme of recent legislation. While watching, from the point of view of results, the action taken by local authorities throughout England for the better prevention of disease, the Board will be superintending the exact province of work for which the respective local authorities under the Act of 1872 are required to appoint their Medical Officers of Health; and the inspections under the Public Health Act, 1858, will therefore, so far as they extend, give the Board knowledge of the working of that new institution in the various forms in which it is being tried throughout the country, and in which, in regard of about half the number of cases, the trial is with the Board's part-payment and particular responsibility. Such inspections, too, as bringing the Board's Medical Department into direct relation with the local Officers of Health, and giving the Department opportunity to contribute any assistance in its power to the success of the local institution, will, where they extend, represent an object which the Royal Sanitary Commission, in making the recommendations on which the Public Health Acts of 1871 and 1872 were founded, put forward as an element of their scheme. As regards that intention of the Royal Sanitary Commission, I need hardly say that, to any holder of my office, it must always be among the highest of ambitions to be able to see the experience of this Department really conducive to the information and influence of younger fellow-labourers in other parts of the same great field of public service; and it would be affectation in me to deny that, during many early years of the new organisation, relations in that sense between the central and local services may often be of important, and sometimes of indispensable, use to the latter. I would, however, also express my confident expectation that, though from the nature of the case the relation in these earlier years must chiefly consist in assistance which the central office can so render, succeeding years will more and more bring the central office under obligation to local contributors of knowledge, and to local illustrations of progress. And year by year it will surely grow to be among the most useful, as it must also be among the happiest, duties of the Annual Reporter under the Public Health Act, 1858, to represent, for the information of all the Officers of Health of the kingdom, such additional fruits of scientific observation, and such new evidences of practical success, as will have come to the Board's knowledge from among their number.

I have the honour to be,
Sir,
Your obedient Servant,
JOHN SIMON.

Medical Department of the
Privy Council and Local
Government Board,
31*st March* 1874.

APPENDIX.

App. No. 1.

Local Administration of Sanitary Law.

No. 1.

INQUIRIES by INSPECTORS with regard to LOCAL ADMINISTRATION of the SANITARY LAWS.

Places.	Date of Inquiry.	Ground of Inquiry.	Authorities concerned.	Name of Inspector, and Précis of Report.
1. Balby-cum-Hexthorpe. (Yorkshire.)	Feb. 1873	Regis.-General's Return. Prevalence of enteric fever.	Doncaster rural sanitary authority.	*Dr. Thorne.* Frequent prevalence of enteric fever. Defective sewerage and drainage. Polluted water supply. Improper means for the disposal of excrement and refuse.
2. Barking - - (Essex.)	Mar. 1873	Regis.-General's Return. Prevalence of enteric fever.	Romford rural sanitary authority.	*Dr. Harries.* Unwholesome water. System of drainage and sewerage imperfect. Passage of sewer air into houses. No arrangements for removal of excrement and refuse. Soil saturated with filth. Overcrowding and other nuisances. Want of hospital accommodation and of means of disinfection.
3. Barking - - - (Lodge Farm.)	May 1873	Question of relation of cases of enteric fever to the sewage irrigation.	- - - -	*Dr. Buchanan.* Enteric fever had occurred among persons living in Barking and working on the sewage farm. No sufficient evidence whether the cause of the fever was on the farm or in the town. Water of a well on the farm derived largely from sewage effluence. Particular excremental nuisances also in the neighbourhood of this well.
4. Bishops Stortford - (Herts.)	May 1873	Regis.-General's Return. Prevalence of enteric fever.	Local board - -	*Dr. Thorne.* Frequent prevalence of enteric fever. Polluted water supply. Sewers imperfectly ventilated, and consequent nuisance from the escape of sewer air into dwellings. Imperfect means for disposal of excrement and refuse. Privies and waterclosets badly constructed, the latter not properly supplied with water.
5. Brecknock - -	Jan. 1873	Regis.-General's Return. Prevalence of fever.	Town council - -	*Dr. Harries.* Defective drainage. Imperfect system of excrement disposal. Cesspits leaky and rarely emptied, and consequent pollution of soil water. Badly constructed and improperly placed privies. Some houses unfit for habitation. Nuisances from animals and from accumulations of manure.
6. Brierley Hill - - (Staffordshire.)	Mar. and June 1873	Continued prevalence of zymotic disease in the Stourbridge registration district.	Local board - -	*Dr. Ballard.* Serious epidemic of small-pox. Sanitary administration very defective. No hospital accommodation or public means for disinfection. Defective system of sewerage. Polluted water. Dilapidated and ill-constructed privies. Nuisance from pigstyes. Dirty, ill-ventilated, and overcrowded cottages.

Places.	Date of Inquiry.	Ground of Inquiry.	Authorities concerned.	Name of Inspector, and Précis of Report.
7. Burnley - - - (Lancashire.)	Mar. and May 1873	Outbreak of small-pox -	Town council - -	*Dr. Beard.* Many old houses constructed without efficient means of ventilation. New houses being built on improper sites. Overcrowding. Defective system of sewerage. Sewage nuisances. Imperfect means for disposal of excrement and refuse. No hospital accommodation. Insufficient sanitary supervision.
8. Campden - - (Gloucestershire.)	May 1873	Prevalence of fever -	Shipston - on - Stour rural sanitary authority.	*Dr. Harries.* Enteric fever has been more or less prevalent for the last three years. Polluted wells. Nuisances from house drainage and from defective system of excrement and refuse disposal. Want of hospital accommodation.
9. Catshill - - - (Worcestershire.)	May 1873	[Inquiry incidental to Redditch inspection.]	Bromsgrove local board	*Dr. Ballard.* Dilapidated and ill-ventilated cottages. No proper drainage. Water supply obtained from a polluted brook. Neglect on the part of the sanitary authority.
10. Combrooke - - (Warwickshire.)	Mar. and May 1873	Outbreak of enteric fever	Stratford - on - Avon rural sanitary authority.	*Dr. Ballard.* Enteric fever had been imported from Leamington, and spread in the house to which the patient was brought and to the two adjoining houses. The water much used in these houses was obtained from a well exposed to pollution. Imperfectly constructed privies in the village generally.
11. Cradley - - - (Worcestershire.)	Mar. and June 1873	Continued prevalence of zymotic disease in the Stourbridge registration district.	Stourbridge rural sanitary authority.	*Dr. Ballard.* Imperfect drainage. No system of excrement and refuse removal. Polluted water. Ill-ventilated and badly drained cottages. Want of sanitary supervision.
12. Doncaster - -	Feb. 1873	Regis.-General's Return.	Town council - -	*Dr. Thorne.* Large general and infantile mortality; endemic enteric fever and diarrhœa; epidemic scarlet fever and small-pox. Polluted water. Bad means of excrement disposal. Escape of sewer air into dwellings. Nuisances from piggeries. Neglected courts. Want of proper means of isolation and disinfection.
13. Edmondsley - (Durham.)	Oct. 1873	Reported mortality from fever. Registrar-General's Return.	Chester-le-Street rural sanitary authority.	*Dr. Harries.* Prevalence of scarlatina. Badly built and ill-ventilated houses. Much overcrowding. General want of privies and refuse bins. Hospital accommodation required.
14. Fleetwood-on-Wyre (Lancashire.)	May 1873	Scarlatina. Registrar-General's Return.	Local board - -	*Dr. Harries.* Serious prevalence of scarlatina. Water partly from wells exposed to pollution. Very defective sewerage. Entrance of sewer air into houses. No system of excrement and refuse removal. Accumulations of many kinds of filth. Undrained inhabited cellars. Overcrowding. No means of isolation or disinfection in cases of infectious disease.
15. Great Baddow - (Essex.)	May 1873	Regis.-General's Return. High rate of mortality from zymotic diseases.	Chelmsford rural sanitary authority.	*Dr. Airy.* Dangerous nuisance from watercourse through the village, which is used as a sewer. Nuisance from a ditch which carries off brewery refuse. No systematic plan of excrement and refuse removal.

Places.	Date of Inquiry.	Ground of Inquiry.	Authorities concerned.	Name of Inspector, and Précis of Report.
16. Guisborough (Yorkshire.)	Aug. 1873	Regis.-General's Return. Fever.	Guisborough local board.	*Dr. Harries.* Serious prevalence of enteric fever. Polluted water. Nuisance from privies and refuse. Imperfect arrangements for scavenging. Ill-built and overcrowded houses.
17. Halesowen (Worcester.)	Mar. and June 1873	Regis.-General's Return. Continued prevalence of zymotic disease in the Stourbridge registration district.	Stourbridge rural sanitary authority.	*Dr. Ballard.* Imperfect drainage. No system of excrement and refuse removal. Polluted water. Ill-ventilated and overcrowded cottages. Want of sanitary supervision.
18. Hucknall-under-Huthwaite. (Nottingham.)	Feb. 1873	Regis.-General's Return. Enteric fever.	Local board	*Dr. Harries.* Water supply insufficient and liable to pollution from surface drainage. Imperfect system of sewerage and of excrement disposal. Roads badly constructed and in a foul condition. Nuisances.
19. Lambeth	Feb. 1873	Typhus fever	Vestry	*Dr. Buchanan.* Serious epidemic of fever in a group of courts dangerously overcrowded. Some of the houses unfit for habitation. Necessity for their removal and for inforcement of regulations against overcrowding.
20. Leicester	Jan. 1873	Hospital for reception of cases of infectious disease.	Town council	*Mr. Radcliffe.* Hospital approved, subject to slight alterations.
21. Littleport (Cambridgeshire.)	Sept. 1873	High rate of mortality from fever.	Ely rural sanitary authority.	*Dr. Thorne.* Water supply generally insufficient and in part polluted. Nuisances from imperfect drainage and from cesspools and privies. No proper provision for removal of excrement and refuse. Some cottages dilapidated and otherwise unfit for habitation.
22. Lye, The	June 1873	Regis.-General's Return. Fever.	Stourbridge rural sanitary authority.	*Dr. Ballard.* No proper drainage. Insufficient supply of water. Polluted wells. Nuisances from accumulations of manure and from privies and ashpits.
23. Macclesfield: Certain portions of the Union. (Cheshire.)	Jan. 1873	Information of prevalence of scarlet fever, enteric fever, and diarrhœa.	Macclesfield rural sanitary authority. Bollington local board.	*Dr. Thorne.* Epidemic of scarlet fever, and frequent prevalence of enteric fever and diarrhœa. No means either of isolation or of disinfection. Bad cottage property. Polluted water. Insufficient and imperfect drainage. Bad arrangements for disposal of excrement and refuse.
24. Margate (Kent.)	Apr. 1873	Prevalence of zymotic disease.	Town council	*Dr. Harries.* Main sewer so constructed as to form a reservoir for sewage, which the tide occasionally drives back through the gratings. Nuisances from sewage outfalls. Rocks and beach near jetty covered with sewage slime. Cesspits estimated to cover aggregate extent of three acres; many under houses, and discharging foul air into them, the sewage sometimes even welling up through the floors. Various nuisances. Prevalence of low-type diseases.
25. Marylebone, St. (Middlesex.)	Aug. 1873	Prevalence of enteric fever	Marylebone vestry	*Mr. Radcliffe.* (Preliminary report.) Outbreak of enteric fever. Probably arose from the distribution of milk from a farmhouse in the neighbourhood of Brill, at which a case of enteric fever had recently occurred.

Places.	Date of Inquiry.	Ground of Inquiry.	Authorities concerned.	Name of Inspector, and Précis of Report.
26. Mendham - - (Suffolk and Norfolk.)	Mar. 1873	Information of the continued prevalence of enteric fever.	Hoxne rural sanitary authority.	*Dr. Airy.* Prevalence of enteric fever. Wells polluted by sewage. Insufficient privy accommodation. No systematic removal of excrement.
27. Mexborough - - (Yorkshire.)	Feb. 1873	Regis.-General's Return. Prevalence of fever, scarlet fever, and small-pox.	Local board, Mexborough.	*Dr. Thorne.* Habitual prevalence of enteric fever. Epidemic of scarlet fever and small-pox. Bad and insufficient drainage. Polluted water. Accumulations of excrement and filth. No proper means of disinfection and isolation.
28. Moseley and Balsall Heath. (Worcestershire.)	Jan. and Feb. 1873.	Outbreak of enteric fever	Balsall Heath local board. King's Norton rural sanitary authority.	*Dr. Ballard.* Enteric fever broke out at a dairyman's. Fever evacuations thrown out into the privy. Fever spread among customers of two dairymen whose wells were polluted by soakage from this privy.
29. Ovenden - - (Yorkshire.)	Mar. 1873	Regis.-General's Return. Prevalence of infectious diseases.	Local board - -	*Dr. Thorne.* Large general and infantile mortality. Prevalence of enteric and scarlet fever. Instances of water pollution. Insufficient means of drainage. Bad means of excrement disposal. No provision for isolation or disinfection.
30. Quarry Bank - (Stafford.)	Mar. and June 1873.	Continued prevalence of zymotic disease in the Stourbridge registration district.	Quarry Bank local board.	*Dr. Ballard.* Serious epidemic of small-pox. Polluted water. No system of drainage. Badly constructed and overfull privies. Dirty, ill-ventilated, and overcrowded cottages. Nuisances of all kinds. General want of sanitary supervision.
31. Redditch - - (Worcestershire.)	May 1873	Prevalence of small-pox -	Redditch local board. Bromsgrove guardians.	*Dr. Ballard.* Epidemic of small-pox. No proper means provided for isolation or disinfection. Defective sewerage. Polluted water. Bad means of excrement disposal.
32. Sherborne - - (Dorset.)	May 1873	Prevalence of enteric fever	Local board - -	*Dr. Blaxall.* Epidemic of enteric fever. No provision for removal of house refuse. Sewerage and drainage imperfect. Waterclosets and privies badly constructed. Escape of sewer air into houses. Overcrowding.
33. Skegby and Fulwood. (Notts.)	Feb. 1873	Regis.-General's Return. Enteric fever.	Mansfield rural sanitary authority.	*Dr. Harries.* New houses at Skegby built without due regard to sanitary considerations. Polluted water. Nuisance from drainage.
34. Springfield - - (Essex.)	May 1873	Regis.-General's Return. High rate of mortality from zymotic diseases.	Chelmsford rural sanitary authority.	*Dr. Airy.* Serious outbreak of diphtheria. Overflowing cesspools close to houses. No system of excrement and refuse removal. Water obtained from wells sunk in sewage-polluted soil. Want of hospital accommodation.
35. Stevenage - - (Herts.)	Jan. 1873	Information of an outbreak of enteric fever.	Hitchin rural sanitary authority.	*Dr. Thorne.* Frequent prevalence of enteric fever. Very imperfect conditions of sewerage and drainage. Polluted water. Want of proper means for the disposal of excrement and refuse. Dilapidated cottage property.
36. Stourbridge - - (Worcestershire.)	Mar. and June 1873.	Continued prevalence of zymotic disease in the Stourbridge registration district.	Improvement commissioners.	*Dr. Ballard.* Serious epidemic of small-pox. Want of hospital accommodation and proper means of disinfection. Insufficient and imperfect system of sewerage. Untrapped drains. Polluted water. Much nuisance from imperfectly constructed privies.

Places.	Date of Inquiry.	Ground of Inquiry.	Authorities concerned.	Name of Inspector, and Précis of Report.
37. Sutton-in-Ashfield (Notts.)	Feb. 1873	Regis.-General's Return, Enteric fever.	Sutton local board -	*Dr. Harries.* Wells exposed to pollution by surface drainage. Sewers unsuitable and insufficient. Improper system of sewage disposal. Insufficient privy accommodation. Nuisance from overflowing privies.
38. Thames - - - (Districts below bridge.)	Aug. and Sept. 1873.	Complaints of inhabitants as to offensive trades carried on along the shores.	Greenwich board of works; West Ham local board; Romford rural sanitary authority; Dartford rural sanitary authority.	*Dr. Ballard.* Eighteen factories inspected. Highly offensive odours from glue and manure works, especially those on Erith marshes (which cause "intolerable nuisances"), and from manufactories of oil of vitriol. Imperfect arrangements for preventing escape of sulphurous acid gas.
39. Tottenham - - (Middlesex.)	Apr. and May 1873.	Continued high rate of mortality from fever and diarrhœa, as shown by the Registrar-General's Return. Serious outbreak of enteric fever.	Local board - -	*Mr. Radcliffe.* Absence of proper ventilation of sewers. Water supply contaminated with decaying animal refuse. Ill-designed cesspools in parts not sewered. Nuisance from watercourses and ditches used as sewers; and from large deposit of sewage mud at the sewage works. Flow of sewage from the sewers disturbed by flood in February, consequent effusion of sewage on the lower parts of the village, and the escape of sewer air into the houses on the higher levels.
40. Ward, East - - (Appleby.)	Nov. 1873	Deaths reported as resulting from vaccination.	Rural sanitary authority.	*Dr. Ballard.* Vaccination from an inflamed arm had caused erysipelas. The practitioner was not a Public Vaccinator.
41. Wigan - - - (Lancashire.)	Feb. 1873	Continued prevalence of diarrhœa.	Town council - -	*Mr. Radcliffe.* Some action has been taken by corporation to carry out recommendations contained in Dr. Buchanan's report (made in 1870), but much still remains to be done.
42. Ystradgunlais - (Brecon.)	Apr. 1873	Regis.-General's Return. Prevalence of enteric fever.	Neath rural sanitary authority.	*Dr. Harries.* Serious prevalence of enteric fever. Polluted water. General want of privy accommodation. No proper means of isolating cases of infectious disease. No arrangements for removal of house refuse.

No. 2.

App. No. 2.

Inspection of Public Vaccination.

List (alphabetically arranged) of 354 **Unions** inspected during the year 1873, with reference to their **Proceedings** under the Vaccination Acts, 1867 and 1871; and an **Account** of the **Awards** made to the respective **Public Vaccinators** out of moneys voted by Parliament for that purpose.

Union.	Number of Vaccination Districts in Union.	Number of respective Vaccination Contractors recommended for Awards. First Class Awards.	Second Class Awards.	Range of Awards in each Union. Minimum. £ s. d.	Maximum. £ s. d.	Total Sum awarded in the Union. £ s. d.	Name of Inspector.
Aberaeron	2	—	—	—	—	—	Dr. Airy.
Aberystwith	5	—	1	—	—	4 2 8	Do.
Abingdon	6	1	—	—	—	4 0 0	„ Stevens.
Alcester	5	—	—	—	—	—	„ Ballard.
Alderbury	6	1	—	—	—	4 7 0	„ Blaxall.
Amersham	7	2	1	4 4 0	6 7 0	14 17 8	„ Thorne.
Amesbury	2	1	—	—	—	12 16 0	„ Blaxall.
Anglesey	3	1	—	—	—	15 11 0	Do.
Asaph, St.	5	—	—	—	—	—	Do.
Ashford, East	6	2	2	1 15 0	6 14 0	17 9 0	„ Stevens.
Ashford, West	3	1	2	2 12 8	16 9 0	22 4 4	Do.
Aston	7	1	—	—	—	64 16 0	„ Ballard.
Atcham	6	—	—	—	—	—	„ Blaxall.
Atherstone	2	—	—	—	—	—	„ Ballard.
Aylesbury	7	5	—	6 1 0	10 0 0	39 16 0	„ Thorne.
Aylsham	7	1	—	—	—	2 14 0	„ Airy.
Aysgarth	3	2	1	2 2 0	3 6 0	7 16 0	„ Harries.
Bala	3	1	—	—	—	13 16 0	„ Blaxall.
Banbury	6	1	1	2 4 0	6 2 0	8 6 0	„ Thorne.
Bangor and Beaumaris	5	—	—	(Under consideration.)			„ Blaxall.
Barnsley	6	2	—	2 15 0	18 9 0	21 4 0	„ Beard.
Barton-upon-Irwell	6	2	—	5 9 0	22 1 0	27 10 0	Do.
Beaminster	5	—	—	—	—	—	„ Blaxall.
Bedale	3	—	1	—	—	3 17 4	„ Harries.
Billericay	5	—	—	—	—	—	„ Airy.
Birkenhead	3	—	—	—	—	—	„ Beard.
Birmingham	4	1	—	—	—	268 3 0	„ Seaton.
Blackburn	10	4	1	5 15 0	50 1 0	164 0 8	„ Beard.
Blandford	4	—	—	—	—	—	„ Blaxall.
Blean	4	1	—	—	—	12 7 0	„ Stevens.
Bolton	11	5	—	13 9 0	31 12 0	100 18 0	„ Beard.
Bradfield	6	3	—	4 6 0	4 17 0	13 11 0	„ Stevens.
Bradford (Wilts)	5	—	—	—	—	—	„ Blaxall.
Bradford (N. York)	7	4	—	24 17 0	42 4 0	125 1 0	„ Beard.
Braintree	4	1	—	—	—	5 4 0	„ Airy.
Bramley	5	2	—	5 9 0	18 19 0	24 8 0	„ Beard.
Brecknock	3	—	—	—	—	—	„ Airy.
Bridge	5	1	1	3 6 8	4 18 0	8 4 8	„ Stevens.
Bridgend & Cowbridge	4	—	—	—	—	—	„ Airy.
Bridgenorth	3	—	—	—	—	—	„ Blaxall.
Brighton	2	1	1	20 8 0	38 18 0	59 6 0	„ Stevens.
Brixworth	6	2	—	2 7 0	4 4 0	6 11 0	„ Thorne.
Bromley	4	1	2	2 1 4	10 17 0	23 6 4	„ Stevens.
Bromsgrove	5	1	1	0 18 8	8 4 0	9 2 8	„ Ballard.
Bromwich, West	5	—	—	—	—	—	Do.
Bromyard	2	—	1	—	—	1 17 4	„ Airy.
Buckingham	3	—	—	—	—	—	„ Thorne.
Builth	1	—	—	—	—	—	„ Airy.
Burnley	7	3	—	5 10 0	11 18 0	28 14 0	„ Beard.
Burton-on-Trent	8	2	—	5 12 0	13 12 0	19 4 0	„ Ballard.
Bury	6	1	—	—	—	8 10 0	„ Beard.

Union.	Number of Vaccination Districts in Union.	Number of respective Vaccination Contractors recommended for Awards. First Class Awards.	Second Class Awards.	Range of Awards in each Union. Minimum. £	s.	d.	Maximum. £	s.	d.	Total Sum awarded in the Union. £	s.	d.	Name of Inspector.
Calne	1	—	—		—			—			—		Dr. Blaxall.
Canterbury	1	—	1		—			—		16	5	4	,, Stevens.
Cardiff	6	2	—	2	5	0	16	0	0	18	5	0	,, Airy.
Cardigan	3	—	1		—			—		8	6	0	Do.
Carmarthen	8	1	—		—			—		7	1	0	Do.
Carnarvon	5	—	—		—			—			—		,, Blaxall.
Cerne	5	—	—		—			—			—		Do.
Chailey	4	—	1		—			—		6	2	8	,, Stevens.
Cheadle	5	—	—		—			—			—		,, Ballard.
Chelmsford	10	2	—	3	5	0	5	10	0	8	15	0	,, Airy.
Chelsea	2	—	—		—			—			—		,, Stevens.
Chester	3	1	—		—			—		68	19	0	,, Beard.
Chester-le-Street	2	1	1	33	1	4	41	3	0	74	4	4	,, Harries.
Chichester	1	—	1		—			—		4	8	0	,, Stevens.
Chippenham	7	1	—		—			—		3	3	0	,, Blaxall.
Chorley	5	—	—	(Under consideration.)									,, Beard.
Chorlton	11	—	—		—			—			—		Do.
Church Stretton	4	1	—		—			—		3	3	0	,, Blaxall.
Cleobury Mortimer	2	1	1	5	19	4	8	10	0	14	9	4	Do.
Clithero	5	—	—		—			—			—		,, Beard.
Clun	3	—	—		—			—			—		,, Blaxall.
Colchester	1	1	—		—			—		38	13	0	,, Airy.
Congleton	4	1	—		—			—		20	7	0	,, Beard.
Conway	2	—	—		—			—			—		,, Blaxall.
Cookham	4	1	—		—			—		8	3	0	,, Stevens.
Corwen	3	—	—		—			—			—		,, Blaxall.
Cranbrook	6	3	1	1	6	0	8	13	0	20	12	4	,, Stevens.
Crickhowel	2	1	—		—			—		47	2	0	,, Airy.
Cricklade & Wootton Bassett	3	—	—		—			—			—		,, Blaxall.
Cuckfield	6	—	—	(Under consideration.)									,, Stevens.
Darlington	5	1	1	7	0	0	28	1	4	35	1	4	,, Harries.
Dartford	5	4	—	9	13	0	23	16	0	69	5	0	,, Stevens.
Daventry	7	3	—	1	14	0	10	18	0	18	18	0	,, Thorne.
Depwade	7	2	1	2	19	0	10	4	0	18	3	0	,, Airy.
Devizes	7	—	—		—			—			—		,, Blaxall.
Dolgelly	5	—	—		—			—			—		Do.
Dorchester	6	—	—		—			—			—		Do.
Dore	3	1	—		—			—		10	10	0	,, Airy.
Dover	4	—	—		—			—			—		,, Stevens.
Downham	6	1	—		—			—		16	12	0	,, Airy.
Drayton	5	2	—	2	6	0	3	2	0	5	8	0	,, Blaxall.
Droitwich	6	—	—		—			—			—		,, Ballard.
Dulverton	3	—	—		—			—			—		,, Blaxall.
Dudley	8	4	—	31	15	0	56	16	0	177	4	0	,, Ballard.
Dunmow	6	—	—		—			—			—		,, Airy.
Durham	4	—	—		—			—			—		,, Harries.
Easington	4	1	—		—			—		17	18	0	Do.
Easingwold	4	2	—	2	19	0	5	7	0	8	6	0	Do.
East Grinstead	5	2	1	4	14	8	8	12	0	18	14	8	,, Stevens.
East Hampstead	3	1	—		—			—		2	15	0	Do.
East Preston	4	—	2	4	12	8	6	16	8	11	9	4	Do.
Eastry	7	2	—	4	10	0	4	13	0	9	3	0	Do.
Ecclesall Bierlow	3	3	—	12	13	0	72	2	0	146	12	0	,, Beard.
Elham	5	—	—		—			—			—		,, Stevens.
Ellesmere	7	—	—		—			—			—		,, Blaxall.
Epping	9	—	—		—			—			—		,, Airy.
Erpingham	3	—	—		—			—			—		Do.
Eton	8	3	—	5	19	0	11	18	0	24	6	0	,, Thorne.
Evesham	5	1	1	4	16	0	6	17	0	11	13	0	,, Ballard.
Faringdon	4	1	—		—			—		4	15	0	,, Stevens.
Faversham	4	1	—		—			—		14	6	0	Do.
Festiniog	4	—	—		—			—			—		,, Blaxall.
Flegg, East and West	4	—	—		—			—			—		,, Airy.
Foleshill	5	—	—		—			—			—		,, Ballard.
Forden	4	—	1		—			—		5	2	8	,, Blaxall.
Fylde, The	5	2	—	11	19	0	18	7	0	30	6	0	,, Beard.

Union.	Number of Vaccination Districts in Union.	Number of respective Vaccination Contractors recommended for Awards.		Range of Awards in each Union.		Total Sum awarded in the Union.	Name of Inspector.
		First Class Awards.	Second Class Awards.	Minimum.	Maximum.		
				£ s. d.	£ s. d.	£ s. d.	
Garstang	3	—	—	—	—	—	Dr. Beard.
George, St., East	1	1	—	—	—	58 1 0	„ Stevens.
Giles, St., and St. Geo., Bloomsbury	1	—	—	—	—	—	Do.
Goole	5	1	2	2 15 4	6 14 0	12 6 8	„ Beard.
Gower	2	1	—	—	—	5 12 0	„ Airy.
Gravesend and Milton	1	1	—	—	—	22 5 0	„ Stevens.
Guiltcross	5	2	—	3 19 0	4 9 0	8 8 0	„ Airy.
Guisborough	6	—	1	—	—	11 14 0	„ Harries.
Hackney	4	3	—	17 1 0	29 2 0	72 19 0	„ Stevens.
Halifax	9	4	—	23 5 0	113 10 0	188 1 0	„ Beard.
Halstead	5	1	—	—	—	4 16 0	„ Airy.
Hardingstone	3	3	—	5 13 0	8 2 0	20 3 0	„ Thorne.
Hartlepool	3	2	—	35 14 0	48 16 0	84 10 0	„ Harries.
Haslingden	6	—	—	—	—	—	„ Beard.
Haverfordwest	4	—	—	—	—	—	„ Airy.
Hawarden	3	—	—	—	—	—	„ Blaxall.
Hay	3	1	—	—	—	8 19 0	„ Airy.
Helmsley Blackmoor	2	2	—	3 19 0	6 7 0	10 6 0	„ Harries.
Hemsworth	5	—	—	—	—	—	„ Beard.
Hereford	4	1	—	—	—	30 17 0	„ Airy.
Highworth & Swindon	4	—	—	—	—	—	„ Blaxall.
Holbeck	1	1	—	—	—	40 9 0	„ Beard.
Holborn	4	—	—	—	—	—	„ Stevens.
Hollingbourn	6	1	—	—	—	3 17 0	Do.
Holyhead	3	—	1	—	—	5 11 4	„ Blaxall.
Holywell	5	1	—	—	—	23 10 0	Do.
Hoo	1	1	—	—	—	5 17 0	„ Stevens.
Horsham	8	6	—	3 8 0	8 15 0	29 16 0	Do.
Houghton-le-Spring	4	2	—	17 18 0	23 19 0	41 17 0	„ Harries.
Huddersfield	15	12	—	6 1 0	37 14 0	209 10 0	„ Beard.
Hungerford	5	—	2	4 10 8	4 12 0	9 2 8	„ Stevens.
Hunslet	3	—	—	—	—	—	„ Beard.
Islington	4	1	—	—	—	31 0 0	„ Stevens.
Kensington	3	1	—	—	—	23 17 0	Do.
Keighley	4	2	—	11 9 0	11 12 0	23 1 0	„ Beard.
Kettering	4	2	—	8 0 0	22 15 0	30 15 0	„ Thorne.
Kidderminster	5	1	—	—	—	5 3 0	„ Ballard.
King's Norton	7	—	2	3 3 4	31 18 8	35 2 0	Do.
Kington	5	3	—	3 10 0	18 14 0	22 8 0	„ Airy.
Kirkby Moorside	1	1	—	—	—	8 4 0	„ Harries.
Knaresborough	3	1	—	—	—	6 12 0	„ Beard.
Knighton	4	—	—	—	—	—	„ Airy.
Lambeth	2	1	—	—	—	50 18 0	„ Stevens.
Lampeter	2	—	—	—	—	—	„ Airy.
Lancaster	5	—	—	—	—	—	„ Beard.
Lanchester	4	—	—	—	—	—	„ Harries.
Ledbury	3	2	—	6 19 0	7 17 0	14 16 0	„ Airy.
Leeds	6	3	—	10 18 0	66 6 0	102 19 0	„ Seaton.
Leek	5	2	—	1 8 0	10 0 0	11 8 0	„ Ballard.
Leigh	3	2	—	27 11 0	28 14 0	56 5 0	„ Beard.
Leominster	2	—	—	—	—	—	„ Airy.
Lewes	1	—	—	—	—	—	„ Stevens.
Lewisham	5	—	—	—	—	—	Do.
Lexden and Winstree	9	5	1	3 1 0	10 15 0	34 17 8	„ Airy.
Leyburn	6	—	1	—	—	0 11 4	„ Harries.
Lichfield	6	2	2	1 8 0	17 16 8	28 2 8	„ Ballard.
Liverpool	3	3	—	103 12 0	208 2 0	480 2 0	„ Seaton.
Llandilo Fawr	4	1	—	—	—	17 6 0	„ Airy.
Llanelly	2	—	—	—	—	—	Do.
Llanfyllin	5	—	—	—	—	—	„ Blaxall.
Llanrwst	2	1	—	—	—	7 15 0	Do.
Loddon and Clavering	4	2	—	9 1 0	10 4 0	19 5 0	„ Airy.
London, City	2	2	—	21 19 0	28 3 0	50 2 0	„ Stevens.
Ludlow	5	—	—	—	—	—	„ Blaxall.
Lunesdale	5	—	—	—	—	—	„ Beard.

Union.	Number of Vaccination Districts in Union.	Number of respective Vaccination Contractors recommended for Awards. First Class Awards.	Second Class Awards.	Range of Awards in each Union. Minimum. £ s. d.	Maximum. £ s. d.	Total Sum awarded in the Union. £ s. d.	Name of Inspector.
Macclesfield	5	2	—	1 17 0	16 6 0	18 3 0	Dr. Beard.
Machynlleth	5	—	—	—	—	—	" Blaxall.
Madeley	4	1	—	—	—	11 4 0	Do.
Maidstone	5	2	—	11 10 0	53 5 0	64 15 0	" Stevens.
Maldon	7	—	—	—	—	—	" Airy.
Malling	4	1	1	8 8 0	16 17 0	25 5 0	" Stevens.
Malmesbury	4	—	—	—	—	—	" Blaxall.
Malton	8	2	2	4 2 0	5 14 0	19 14 4	" Harries.
Manchester	5	5	—	31 17 0	123 7 0	379 4 0	" Seaton.
Marlborough	2	—	—	—	—	—	" Blaxall.
Martley	5	—	—	—	—	—	" Ballard.
Marylebone	1	1	—	—	—	142 12 0	" Stevens.
Medway	3	2	—	32 17 0	51 5 0	84 2 0	Do.
Melksham	2	—	1	—	—	16 0 0	" Blaxall.
Mere	2	—	—	—	—	—	Do.
Meriden	4	1	—	—	—	9 9 0	" Ballard.
Merthyr Tydfil	9	—	—	—	—	—	" Airy.
Midhurst	5	3	—	3 7 0	10 7 0	19 8 0	" Stevens.
Mile End Old Town	2	—	—	—	—	—	Do.
Milton	2	1	—	—	—	14 17 0	Do.
Mitford & Launditch	8	2	1	1 7 0	6 6 8	13 2 8	" Airy.
Nantwich	8	1	—	—	—	7 5 0	" Beard.
Narberth	4	—	—	—	—	—	" Airy.
Neath	8	4	1	9 5 4	56 12 0	186 1 4	Do.
Newbury	3	—	1	—	—	3 17 4	" Stevens.
Newcastle-in-Emlyn	3	—	—	—	—	—	" Airy.
Newcastle-under-Lyme	3	1	1	1 8 8	36 16 0	38 4 8	" Ballard.
Newcastle-on-Tyne	7	—	—	—	—	—	" Seaton.
Newhaven	5	2	2	0 13 4	7 9 0	10 10 0	" Stevens.
Newport (Salop)	4	1	—	—	—	6 15 0	" Blaxall.
Newport Pagnell	11	2	—	2 3 0	9 6 0	11 9 0	" Thorne.
Newtown & Llanidloes	5	—	—	—	—	—	" Blaxall.
Northallerton	4	—	1	—	—	1 9 4	" Harries.
Northampton	4	2	—	12 1 0	22 12 0	34 13 0	" Thorne.
North Aylesford	2	1	—	—	—	19 14 0	" Stevens.
North Bierley	12	6	—	5 14 0	27 3 0	92 5 0	" Beard.
Northwich	7	2	—	2 11 0	14 13 0	17 4 0	Do.
Nuneaton	2	—	—	—	—	—	" Ballard.
Ongar	6	—	—	—	—	—	" Airy.
Ormskirk	5	1	—	—	—	6 0 0	" Beard.
Orsett	5	2	—	6 3 0	8 3 0	14 6 0	" Airy.
Oswestry	5	—	—	—	—	—	" Blaxall.
Oundle	4	3	—	4 12 0	9 9 0	19 14 0	" Thorne.
Ouseburn, Great	5	2	—	2 9 0	5 18 0	8 7 0	" Beard.
Pancras, St.	1	1	—	—	—	194 1 0	" Stevens.
Pateley Bridge	3	2	—	3 11 0	14 9 0	18 0 0	" Beard.
Pembroke	6	3	2	5 14 8	12 10 0	45 13 0	" Airy.
Penistone	3	1	—	—	—	18 10 0	" Beard.
Penkridge	3	1	—	—	—	21 3 0	" Ballard.
Pershore	5	4	—	2 7 0	10 13 0	26 8 0	Do.
Peterborough	7	4	—	4 8 0	30 16 0	51 14 0	" Thorne.
Petworth	4	2	1	2 3 0	7 2 0	11 11 0	" Stevens.
Pewsey	4	1	—	—	—	8 18 0	" Blaxall.
Pickering	3	1	—	—	—	10 12 0	" Harries.
Pontefract	7	—	—	(Under consideration.)			" Beard.
Pontypridd	8	3	1	12 17 0	26 11 0	87 11 4	" Airy.
Poole	4	1	—	—	—	13 4 0	" Blaxall.
Potterspury	4	1	—	—	—	14 15 0	" Thorne.
Prescot	8	1	—	—	—	53 9 0	" Beard.
Presteigne	1	1	—	—	—	8 17 0	" Airy.
Preston	8	—	—	(Under consideration.)			" Beard.
Pwllheli	5	1	—	—	—	8 1 0	" Blaxall.
Reading	7	—	—	—	—	—	" Stevens.
Reeth	2	—	—	—	—	—	" Harries.
Rhayader	1	—	—	—	—	—	" Airy.
Richmond (Yorks.)	5	3	—	1 11 0	5 13 0	10 7 0	" Harries.
Ripon	4	2	—	3 2 0	3 14 0	6 16 0	" Beard.

APP. No. 2.

Inspection of Public Vaccination.

Union.	Number of Vaccination Districts in Union.	Number of respective Vaccination Contractors recommended for Awards. First Class Awards.	Second Class Awards.	Range of Awards in each Union. Minimum. £ s. d.	Maximum. £ s. d.	Total Sum awarded in the Union. £ s. d.	Name of Inspector.
Rochdale	7	2	—	3 15 0	63 4 0	65 19 0	Dr. Beard.
Rochford	5	—	1	—	—	4 3 4	" Airy.
Romford	7	—	—	—	—	—	Do.
Romney Marsh	3	1	—	—	—	6 3 0	" Stevens.
Ross	4	1	—	—	—	17 12 0	" Airy.
Rugby	8	—	—	—	—	—	" Ballard.
Ruthin	3	—	—	—	—	—	" Blaxall.
Saddleworth	1	1	—	—	—	96 18 0	" Beard.
Saffron Walden	8	4	—	1 7 0	6 10 0	15 9 0	" Airy.
Scarborough	5	3	—	2 2 0	10 4 0	15 2 0	" Harries.
Sedbergh	3	1	—	—	—	2 13 0	" Beard.
Sedgefield	4	—	—	—	—	—	" Harries.
Seisdon	4	—	—	—	—	—	" Ballard.
Selby	5	3	—	3 4 0	22 7 0	34 18 0	" Beard.
Settle	8	3	1	0 12 0	9 10 0	16 11 0	Do.
Sevenoaks	6	—	1	—	—	6 0 0	" Stevens.
Shaftesbury	3	1	—	—	—	11 16 0	" Blaxall.
Sheppey	2	2	—	7 7 0	30 17 0	38 4 0	" Stevens.
Shepton Mallet	4	—	—	—	—	—	" Blaxall.
Sherborne	3	—	—	—	—	—	Do.
Shiffnal	4	—	—	—	—	—	Do.
Shipston-on-Stour	3	—	—	—	—	—	" Ballard.
Skipton	5	—	—	—	—	—	" Beard.
Smallburgh	4	—	1	—	—	2 6 8	" Airy.
Solihull	6	—	1	—	—	2 7 4	" Ballard.
Southam	4	—	—	—	—	—	Do.
South Shields	3	—	2	5 13 4	45 16 8	52 8 0	" Harries.
Stafford	4	2	—	6 12 0	10 4 0	30 16 0	" Ballard.
Stockton-on-Tees	6	—	2	16 18 0	36 12 0	53 10 0	" Harries.
Stokesley	4	—	—	—	—	—	Do.
Stoke-upon-Trent	3	4	—	6 9 0	40 17 0	106 14 0	" Ballard.
Stone	4	2	—	3 6 0	75 5 0	78 11 0	Do.
Stourbridge	5	1	1	4 13 4	53 0 0	57 13 4	Do.
Strand	1	—	—	—	—	—	" Stevens.
Stratford-on-Avon	7	2	—	7 11 0	14 18 0	22 9 0	" Ballard.
Sturminster	4	—	—	—	—	—	" Blaxall.
Swaffham	6	—	—	—	—	—	" Airy.
Swansea	3	1	—	—	—	118 18 0	Do.
Tadcaster	4	1	—	—	—	4 10 0	" Beard.
Tamworth	5	—	—	—	—	—	" Ballard.
Tarvin	2	—	—	(Under consideration.)			" Beard.
Teesdale	7	3	1	4 11 4	12 6 0	35 6 4	" Harries.
Tenbury	2	—	—	—	—	—	" Ballard.
Tendring	11	1	1	7 12 0	9 2 0	16 14 0	" Airy.
Tenterden	6	—	2	1 19 4	4 9 4	6 8 8	" Stevens.
Thanet, Isle of	4	3	—	9 0 0	22 6 0	52 15 0	Do.
Thetford	7	2	—	3 16 0	8 7 0	14 3 0	" Airy.
Thirsk	6	1	—	—	—	2 3 0	" Harries.
Thorne	6	2	—	4 11 0	14 17 0	19 8 0	" Beard.
Thrapston	5	3	—	1 16 0	13 2 0	18 3 0	" Thorne.
Ticehurst	8	3	1	3 2 8	7 7 0	24 7 8	" Stevens.
Tisbury	3	1	—	—	—	5 4 0	" Blaxall.
Todmorden	4	—	—	—	—	—	" Beard.
Tonbridge	6	2	2	2 15 0	35 12 8	43 7 8	" Stevens.
Towcester	4	2	—	3 1 0	3 16 0	8 17 0	" Thorne.
Toxteth Park	2	1	—	—	—	139 10 0	" Beard.
Tregaron	2	—	—	—	—	—	" Airy.
Upton-on-Severn	4	—	—	—	—	—	" Ballard.
Uttoxeter	5	1	—	—	—	5 5 0	Do.
Wakefield	6	5	1	1 12 0	82 8 0	124 17 0	" Beard.
Wallingford	3	3	—	5 1 0	6 9 0	16 15 0	" Stevens.
Walsall	4	2	—	14 11 0	37 5 0	31 16 0	" Ballard.
Walsingham	6	—	1	—	—	5 4 0	" Airy.
Wandsworth & Clapham	8	5	—	4 17 0	74 1 0	130 8 0	" Stevens.
Wantage	5	—	—	—	—	—	Do.
Wareham and Purbeck	7	—	1	—	—	3 8 8	" Blaxall.
Warminster	5	4	—	1 16 0	6 13 0	19 8 0	Do.

Union.	Number of Vaccination Districts in Union.	Number of respective Vaccination Contractors recommended for Awards. First Class Awards.	Second Class Awards.	Range of Awards in each Union. Minimum. £ s. d.	Maximum. £ s. d.	Total Sum awarded in the Union. £ s. d.	Name of Inspector.
Warrington	3	1	—	—	—	28 6 0	Dr. Beard.
Warwick	3	—	—	—	—	—	„ Ballard.
Wayland	2	—	—	—	—	—	„ Airy.
Weardale	5	—	—	—	—	—	„ Harries.
Wellingborough	4	4	—	9 0 0	18 19 0	55 8 0	„ Thorne.
Wellington (Salop)	3	—	—	—	—	—	„ Blaxall.
Wells	4	—	—	—	—	—	Do.
Wem	4	2	—	2 2 0	2 10 0	4 12 0	Do.
Weobley	3	—	—	—	—	—	„ Airy.
Westbourne	3	—	—	—	—	—	„ Stevens.
West Bromwich	5	2	—	51 16 0	61 9 0	113 5 0	„ Ballard.
Westbury and Whorwelsdown	4	2	—	2 13 0	4 14 0	7 7 0	„ Blaxall.
West Derby	6	1	—	—	—	25 12 0	„ Beard.
West Firle	3	—	1	—	—	0 16 0	„ Stevens.
West Ham	4	—	—	—	—	—	„ Airy.
Westhampnett	5	—	—	—	—	—	„ Stevens.
Westminster	2	1	—	—	—	14 9 0	Do.
Wetherby	6	—	—	—	—	—	„ Beard.
Weymouth	6	2	1	3 11 0	9 11 0	17 7 4	„ Blaxall.
Wharfedale	3	1	—	—	—	14 2 0	„ Beard.
Whitby	5	1	—	—	—	7 18 0	„ Harries.
Whitchurch (Salop)	4	—	—	—	—	—	„ Blaxall.
Whitechapel	1	1	—	—	—	81 0 0	„ Stevens.
Wigan	8	3	—	43 3 0	47 11 0	135 14 0	„ Beard.
Wilton	4	1	—	—	—	6 16 0	„ Blaxall.
Wimborne & Cranborne	4	1	—	—	—	6 9 0	Do.
Windsor	3	1	—	—	—	26 3 0	„ Stevens.
Winslow	8	2	1	3 6 0	10 4 0	22 12 0	„ Thorne.
Wirrall	4	1	—	—	—	9 9 0	„ Beard.
Witham	3	1	—	—	—	12 17 0	„ Airy.
Wokingham	4	—	1	—	—	3 2 8	„ Stevens.
Wolstanton & Burslem	3	1	—	—	—	52 19 0	„ Ballard.
Wolverhampton	5	2	—	44 13 0	73 12 0	118 5 0	Do.
Woolwich	3	2	—	16 11 0	57 19 0	74 10 0	„ Stevens.
Worcester	1	1	—	—	—	34 10 0	„ Ballard.
Wortley	3	—	—	—	—	—	„ Beard.
Wrexham	5	1	—	—	—	60 5 0	„ Blaxall.
Wycombe	12	5	1	2 1 0	13 7 0	45 5 8	„ Thorne.
	1,617	401	82		£	8,508 17 4	

Supplementary List of Awards made in 1873 to Public Vaccinators in Unions which were inspected in 1872.

Union.	Districts	First Class	Second Class	Minimum. £ s. d.	Maximum. £ s. d.	Total. £ s. d.	Inspector.
Altrincham	6	2	—	6 1 0	22 7 0	28 8 0	Dr. Beard.
Ashton-under-Lyne	12	6	—	6 2 0	38 1 0	114 16 0	Do.
Bristol	1	1	—	—	—	73 13 0	„ Seaton.
Chelsea	1	1	—	—	—	25 4 0	Do.
Cosford	6	2	—	6 17 0	8 18 0	15 15 0	„ Harries.
Exeter	1	1	—	—	—	46 14 0	„ Seaton.
Guildford	9	1	1	3 0 8	4 5 0	7 5 8	„ Stevens.
Hoxne	7	4	1	2 9 0	9 19 0	30 12 0	„ Harries.
Oundle	4	2	—	7 3 0	7 13 0	14 16 0	„ Stevens.
Penzance	5	1	—	—	—	7 4 0	„ Blaxall.
Poplar	4	2	—	29 0 0	36 0 0	65 0 0	„ Stevens.
Prestwich	5	1	1	16 3 4	68 15 0	84 18 4	„ Beard.
Stepney	2	1	—	—	—	48 5 0	„ Stevens.
Stockport	5	2	—	19 2 0	51 1 0	70 3 0	„ Beard.
Stow	7	3	—	1 13 0	9 5 0	16 4 0	„ Harries.
Sudbury	7	2	1	8 19 0	21 8 0	42 11 0	Do.
	82	32	4		£	691 9 0	

APP. No. 3.

National Vaccine Establishment.

No. 3.

STATISTICS of the NATIONAL VACCINE ESTABLISHMENT and EDUCATIONAL VACCINATING STATIONS.

I.—STAFF AT END OF 1873.

N.B.—The stations named in *italics* are Educational Vaccinating Stations, authorised by the Local Government Board.

——	Name.	Vaccinating Stations.	Days and Hours of Attendance.
Vaccinators supplying lymph for the public service and salaried from the Parliamentary Grant	1. Mr. J. F. Marson	*Surrey Chapel*	Tues., Thurs.; 1.
	2. Mr. G. L. Cooper	Gt.NorthernHospl.	Tuesday; 12.
	3. Mr. W. E. G. Pearse	*Tottenham Court Chapel.*	Mon., Wednes.; 1.
Parochial and other Vaccinators, not salaried from the Parliamentary Grant, but furnishing lymph at a fixed rate of payment	1. Mr. Ellis S. Guest	*Manchester*	Monday; 2.
	2-5. Dr. Edmund Robinson	*Birmingham*	2. Monday; 3. Tuesday; 4. Wednesd.; 5. Thursday; 11.
	6. Dr. H. A. P. Robertson	*Bristol*	Wednesday; 10.
	7. Mr. A. B. Sheele	*Liverpool*	Thursday; 2.
	8. Mr. E. L. Webb	*Pimlico*	Thursday; 10.
	9. Dr. T. C. Nesham	*Newcastle-on-Tyne*	Thursday; 3.
	10. Mr. W. E. G. Pearse	*Westminster*	Tuesday; 2.
	11-12. Mr. W. A. Sumner	*Marylebone*	Monday; Wednesd.; 10.
	13. Mr. C. T. Blackman	*Whitechapel*	Wednesday; 11.
	14. Mr. Frederick Holmes	*Leeds*	Tuesday; 2.30.
	15. Dr. Edward Lynes	Coventry	Tuesday; 12.
	16. Dr. Hugh Thomson	*Glasgow*	Monday; 12.
	17. Mr. C. Harriot Roper	*Exeter*	Thursday; 3.
	18. Mr. Robert Dunn	*Strand*	Monday; 10.
	19. Dr. Matthew Brownfield	Bromley, Middlesex	Tuesday; 11.
	20. Dr. William Stuart	Woolwich	Thursday; 3.
	21. Mr. George Broadbent	Ancoats	Wednesday; 2.
	22. Mr. W. Skinner	*Sheffield*	Tuesday; 3.
Teachers of Vaccination not supplying lymph	Dr. W. Husband	*Edinburgh*	Wednes., Sat.; 12.
	Dr. R. D. Tannahill	*Glasgow*	Mond., Thurs.; 12.

II.—Sources and Amount of Lymph Supply in 1873.

N.B.—The stations named in *italics* are Educational Vaccinating Stations, authorised by the Local Government Board.

—	Vaccination Stations.	Number of Vaccinations performed at the Stations respectively. Primary.	Re-vaccinations.	Number of Charges of Lymph supplied from the Stations respectively.
Vaccinators salaried from the Parliamentary Grant	1. *Surrey Chapel* -	946	212	14,879
	2. Battle Bridge -	626	2	6,779
	3. Bermondsey* - -	534	12	5,331
	4. *Tottenham Court Chapel.*	1,203	161	13,925
	Total - -	3,309	387	40,914
Parochial and other Vaccinators not salaried from the Parliamentary Grant, but contributing lymph at a fixed rate of payment - - - -	1. *Manchester* - -	1,370	34	8,088
	2–5. *Birmingham* -	5,828	214	25,260
	6. *Bristol* - - -	805	6	4,771
	7. *Liverpool* - -	1,143	2	17,979
	8. *Pimlico* - - -	532	40	7,785
	9. *Newcastle-on-Tyne*†	472	85	8,950
	10. *Westminster* - -	1,158	13	14,974
	11-12. *Marylebone* -	1,932	52	2,544
	13. *Whitechapel* - -	1,198	10	3,867
	14. *Leeds* - - -	1,172	—	3,766
	15. Coventry - -	1,008	3	6,113
	16. *Glasgow*† - -	833	—	7,612
	17. *Exeter* - - -	589	151	140
	18. *Strand* - - -	611	—	1,132
	19. Bromley - -	907	—	7,008
	20. Ancoats - -	1,523	5	32,193
	21. *Sheffield*‡ - -	708	—	2,651
	Total - -	21,789	615	154,783
	General Total -	25,098	1,002	195,697

* For six months only. † For nine months only. ‡ For ten months only.

App. No. 3.

National Vaccine Establishment.

III.—Distribution of Lymph, 1873.

Number of applications:—

From medical practitioners in England and Wales - -	8,491
" " Ireland - - - - -	4
" " Scotland - - -	291
" the army - - - - - - - - - -	446
" the navy and from the emigration department -	65
" India and the colonies - - - - - -	199
" diplomatic and other foreign services - - -	93
Total - - -	9,569

Supplies sent out:—

Charged ivory points - - - - - - -	84,715
" squares of glass - - - - - - -	177
" capillary tubes - - - - - - -	13,249

IV.—Summary for the Years 1856–1873.

Year.	Total Vaccinations performed at the Stations which supply Lymph.	Re-vaccinations, included in preceding column.	Number of charges of Lymph received for distribution.
1856 -	7,039	?	210,942
1857 -	6,327	?	213,207
1858 -	6,445	?	234,150
1859 -	9,030	?	237,801
1860 -	13,849	?	228,347
1861 -	12,009	?	225,000
1862 -	13,149	?	211,475
1863 -	20,600	?	239,432
1864 -	13,727	?	203,250
1865 -	14,648	515	212,832
1866 -	14,319	372	207,014
1867 -	14,911	584	216,637
1868 -	16,092	173	226,825
1869 -	15,790	127	210,417
1870 -	20,460	572	243,005
1871 -	45,300	14,668	307,654
1872 -	32,241	6,466	239,521
1873 -	26,100	1,002	215,672

No. 4.

App. No 4.

Cholera Order as to Ships.

Order of the Local Government Board with respect to Ships suspected of Choleraic Infection.

To all Urban, Rural, and Port Sanitary Authorities ;—
To all Officers of Customs ;—
To all Masters of Ships ;—
And to all others whom it may concern.

Whereas the Lords of Her Majesty's most Honourable Privy Council, by an Order bearing date the 29th day of July 1871, after reciting certain provisions of an Act passed in the Sixth year of the Reign of His Majesty King George the Fourth, chapter seventy-eight, and of the Sanitary Act, 1866, and further that Cholera was then prevailing in certain parts of Continental Europe with which this Country had communication, and that it was requisite to take precaution, as far as practicable, against the introduction of that disease into this Country, did make certain rules, orders, and regulations in respect thereof, and by certain other Orders bearing date respectively the 3rd and 5th days of August 1871, did make further regulations;

And whereas under and by virtue of "The Local Government Board Act, 1871," all powers and duties vested in and imposed on Her Majesty's most Honourable Privy Council by (among others) the said Sanitary Act, 1866, were, as regards England and Wales, transferred to and imposed on the Local Government Board ;

And whereas Cholera is now prevalent in certain parts of Continental Europe with which this country has communication, and it is expedient that the said rules, orders, and regulations should be rescinded, and other rules, orders, and regulations substituted in their place:

Now therefore, We, the Local Government Board, do hereby rescind all such rules, orders, and regulations in the above-recited Orders contained, except in so far as they apply to Scotland, or may apply to any proceedings now pending, and We do hereby Order as follows :—

Definitions.

Art. 1.—In this Order :—

The term "Ship" includes vessel or boat ;

The term "Officer of Customs" includes any person having authority from the Commissioners of Customs ;

The term "Master" includes the officer or person for the time being in charge or command of a ship ;

The term "Cholera" includes Choleraic Diarrhœa ;

The term "Sanitary Authority" has the same meaning as in "The Public Health Act, 1872" ;

The term "Clothing and Bedding" includes all clothing and bedding in actual use and worn or used by the person attacked, at the time of or during the attack of Cholera.

For the purposes of this Order, every ship shall be deemed infected with Cholera, in which there is or has been during the voyage, or during the stay of such ship in a foreign port in the course of such voyage, any case of Cholera.

I.—*Regulations as to Customs Inspection.*

Art. 2.—If any Officer of Customs, on the arrival within the limits of any port in England of any ship, ascertains from the Master of such ship or otherwise, or has reason to suspect, that the ship is infected with Cholera, he may detain such ship, and order the Master forthwith

App. No. 4.

Cholera Order as to Ships.

to moor or anchor the same; and thereupon the Master shall forthwith moor or anchor the ship in such position as such Officer of Customs shall direct.

Art. 3.—Whilst such ship shall be so detained, no person shall leave the same.

Art. 4.—The Officer of Customs detaining any ship as aforesaid, shall forthwith give notice thereof, and of the cause of such detention, to the Port Sanitary Authority, if there be one, or otherwise, to the Sanitary Authority of the District within which the ship shall be detained.

Art. 5.—Such detention by the Officer of Customs shall cease as soon as the said ship shall have been duly visited and examined by the proper Officer of the Sanitary Authority; or, if the ship shall, upon such examination, be found to be infected with Cholera, as soon as the same shall be anchored or moored in pursuance of Art. 9 of this Order.

Provided, that if the examination be not commenced within twelve hours after notice given as aforesaid, the ship shall, on the expiration of the said twelve hours, be released from detention.

II.—*Regulations as to Sanitary Authorities.*

Art. 6.—The Port or other Sanitary Authority at every port shall, as speedily as practicable, with the approval of the Chief Officer of Customs of such port, fix some place or places within the said port where any ship may be detained, moored, or anchored, for the purpose of these regulations.

Art. 7.—Any officer appointed by such Sanitary Authority to see to the carrying out of this Order, if he have reason to believe that any ship arriving within the district of such Authority, whether examined by the Officer of Customs or not, is infected with Cholera, or shall have come from a place infected with Cholera, may visit and examine such ship, for the purpose of ascertaining whether it is so infected; and the Master of such ship shall suffer the same to be so visited and examined.

Art. 8.—The Sanitary Authority, on notice being given to them by an Officer of Customs, under this Order, shall forthwith cause the ship in regard to which such notice shall have been given, to be visited and examined by their Medical Officer of Health, or some other legally qualified Medical Practitioner, for the purpose of ascertaining whether it is infected with Cholera.

Art. 9.—The Master of every ship which is infected with Cholera shall, after any such examination as aforesaid, as long as the ship is within the District of a Sanitary Authority, moor or anchor her in such position as from time to time the said Authority shall direct.

Art. 10.—No person shall leave any such ship until the examination herein-after mentioned shall have been made.

Art. 11.—The Sanitary Authority shall, as soon as possible after the arrival of any such ship, cause all persons on board of the same to be examined by their Medical Officer of Health, or some other legally qualified Medical Practitioner, and shall permit all persons who shall not be certified by him, as hereafter mentioned, to land immediately.

Art. 12.—Every person certified by the Medical Officer of Health, or Medical Practitioner making such examination, to be suffering from Cholera, shall be dealt with under any rules that may have been made by the Sanitary Authority under the 29th section of the Sanitary Act, 1866, or, where no such rules shall have been made, shall be removed, if the condition of the patient admit of it, to some hospital or place

previously appointed for such purpose by the said Authority; and no person so removed shall leave such hospital or place until the Medical Officer of Health of the Authority, or some other legally qualified Medical Practitioner appointed by them, shall have certified that such person is free from the said disease.

If any person suffering from Cholera cannot be removed, the ship shall remain subject, for the purposes of this Order, to the control of the Medical Officer of Health, or some other legally qualified Medical Practitioner appointed by the said Authority; and the infected person shall not be removed from or leave the ship, except with the consent in writing of the Medical Officer of Health or other Medical Practitioner.

Art. 13.—Such Medical Officer of Health or Medical Practitioner shall give directions, and take such steps as may appear to him to be necessary, for preventing the spread of the infection, and the Master of the said Ship shall forthwith carry into execution such directions as shall be given to him by such Officer or Practitioner.

Art. 14.—Any person certified by such Medical Officer of Health or Medical Practitioner as aforesaid to be suffering from any diarrhœal or other illness which he may suspect to be Cholera, may either be detained on board the ship or taken to some hospital or other previously appointed place, and detained there, for any period not exceeding two days, until it be ascertained whether the illness is or is not Cholera.

Any such person who, while so detained, shall be certified by the Medical Officer of Health or Medical Practitioner to be suffering from Cholera, shall be dealt with as in the above Article relating to patients suffering from that disease.

Art. 15.—In the event of any death from Cholera taking place on board of such vessel while so detained, the Master shall cause the dead body to be taken out to sea, and committed to the deep, properly loaded to prevent its rising.

Art. 16.—The Master shall cause the clothing and bedding of every person who may have suffered from Cholera on board such vessel, or who, having at any time been on board such vessel, shall have suffered from Cholera during the stay of such vessel in a Foreign Port, to be disinfected or (if necessary) destroyed; and if the Master shall have neglected to do so before the ship arrives in port, he shall forthwith, or upon the direction of the said Authority, cause the same to be disinfected or destroyed, as the case may require; and if the said Master neglect to comply with such direction within a reasonable time, the Authority shall cause the same to be carried into execution.

Art. 17.—The Master shall cause every part of the ship, and every article therein, other than those last described, which may probably be infected with Cholera, to be disinfected or destroyed, when required to do so by the said Authority, or by their Medical Officer of Health.

Given under our seal of office, this seventeenth day of July, in the year one thousand eight hundred and seventy-three.

(L.S.) JAMES STANSFELD, *President*.

JOHN LAMBERT, *Secretary*.

NOTICE.—The Statute 35 & 36 Vict. c. 79. provides in Section 52 that "any "person wilfully neglecting, or refusing to obey or carry out, or obstructing the "execution of any rule, order, or regulation made by the Local Government Board "under Section 52 of the Sanitary Act, 1866, shall be guilty of an offence punishable "on summary conviction before two Justices, and be liable to a penalty not exceed- "ing *Fifty Pounds*."

App. No. 5.

Precautions against Cholera.

No. 5.

Memorandum on Precautions to be taken against the Infection of Cholera.

1. As Asiatic Cholera is now prevailing in parts of the Continent of Europe, and may probably extend (or perhaps has already extended) to places which are in frequent and rapid communication with England, it is not unlikely that, within the next month or two, cases of the disease may be brought into the ports of this country.

2. The Order, now about to be issued, of the Local Government Board will give power to local Sanitary Authorities to deal with any such cases, if they arrive, in a way to protect the population, as far as practicable, against surprise. But as cases of choleraic infection have widely different degrees of severity, it is possible that some such cases, slightly affected, will, notwithstanding the vigilance of local Authorities, be landed without particular notice in English sea-board towns, whence then they may advance to other, and perhaps inland, places.

3. Former experience of Cholera in England justifies a belief that the presence of imported cases of the disease at various spots in the country will not be capable of causing much injury to the population, if the places receiving the infection have had the advantage of proper sanitary administration; and, in order that all local populations may make their self-defence as effective as they can, it will be well for them to have regard to the present state of knowledge concerning the mode in which epidemics of Cholera (at least in this country) are produced.

4. Cholera in England shows itself so little contagious, in the sense in which small-pox and scarlatina are commonly called contagious, that, if reasonable care be taken where it is present, there is almost no risk that the disease will spread to persons who nurse and otherwise closely attend upon the sick. But cholera has a certain peculiar infectiveness of its own, which, *where local conditions assist*, can operate with terrible force, and at considerable distances from the sick. It is characteristic of Cholera (and as much so of the slightest choleraic diarrhœa as of the disease in its more developed and alarming forms) that *all matters which the patient discharges from his stomach and bowels are infective*. Probably, under ordinary circumstances, the patient has no power of infecting other persons except by means of these discharges; nor any power of infecting even by them, except in so far as particles of them are enabled to taint the food, water, or air, which people consume. Thus, when a case of Cholera is imported into any place, the disease is not likely to spread, unless in proportion as it finds, locally open to it, certain facilities for spreading by *indirect infection*. In order rightly to appreciate what these facilities must be, the following considerations have to be borne in mind:—*first*, that any choleraic discharge, cast without previous thorough disinfection into any cesspool or drain, or other depository or conduit of filth, infects the excremental matters with which it there mingles, and probably, more or less, the effluvia which those matters evolve; *secondly*, that the infective power of choleraic discharges attaches to whatever bedding, clothing, towels and like things, have been imbued with them, and renders these things, if not thoroughly disinfected, as capable of spreading the disease in places to which they are sent (for washing or other purposes) as, in like circumstances, the patient himself would be; *thirdly*, that if, by leakage or soakage from cesspools or drains, or through reckless casting out of slops and wash-water, any taint (however small) of the infective material gets access to wells or other sources of drinking-water, it imparts to enormous volumes

f water the power of propagating the disease. When due regard is ad to these possibilities of indirect infection, there will be no difficulty 1 understanding that even a single case of Cholera, perhaps of the lightest degree, and perhaps quite unsuspected in its neighbourhood, nay, *if local circumstances co-operate*, exert a terribly infective power n considerable masses of population.

5. It might be supposed that, under those provisions of the Sanitary Acts which relate to precautions against dangerous infections of disease, ecurity could be taken, as regards the infective discharges of Cholera, gainst various kinds of personal conduct which would be dangerous to he public health : above all, that, under those provisions or otherwise, he universal disinfection of such discharges could be enforced. Jndoubtedly everything possible in this direction ought to be done, vherever a case of Cholera is known to exist : too much importance annot be attached to the precaution of thoroughly disinfecting, without lelay, all discharges from the stomach and bowels of persons suffering inder the disease, and of disinfecting or destroying all bedding, clothing, owels, and the like, which such discharges may have imbued: and of ourse neither choleraic discharges, nor any slops which may contain races of them, should ever (even when supposed to be disinfected) be ast into any position from which they may get access into drinking-vater. But, although the duty of observing those precautions is one vhich ought never to be neglected, populations cannot prudently stake heir lives on the chance that it will be completely fulfilled for them. Apart from all questions of negligence, the degrees of Cholera are too nany, and the slight and incipient cases far too apt to escape observation, for any such defence against its infection to be more than artial. And therefore the main object for endeavour must be, TO ECURE EVERYWHERE SUCH LOCAL CIRCUMSTANCES THAT THE INFECTIVE MATERIAL, THOUGH NOT DISINFECTED, WOULD BE UNABLE TO PREAD ITS INFLUENCE AMONG THE POPULATION.

6. The dangers which have to be guarded against as favouring the pread of Cholera-infection are particularly two. First, and above all, iere is the danger of WATER-SUPPLIES which are in any (even the ightest) degree tainted by house-refuse or other like kinds of filth ; s where there is outflow, leakage or filtration, from sewers, houserains, privies, cesspools, foul ditches or the like, into springs, streams, ells or reservoirs, from which the supply of water is drawn, or into ie soil in which the wells are situate : a danger which may exist on a nall scale (but perhaps often repeated in the same district) at the imp or dip-well of a private house, or, on a large and even vast scale, the source of public waterworks. And secondly, there is the inger of breathing AIR which is foul with effluvia from the same sorts impurity.

7. Information as to the high degree in which those two dangers ect the public health in ordinary times, and as to the special imrtance which attaches to them at times when any diarrhœal infection likely to be introduced, has now for so many years been before the blic, that the improved systems of refuse-removal and water-supply which the dangers are permanently obviated for large populations, d also the minor structural improvements by which separate houselds are secured against them, ought long ago to have come into iversal use.

So far, however, as this wiser course has not been adopted, temrary security must, as far as practicable, be sought in measures of a lliative kind.

(*a.*) Immediate and searching examination of sources of water-supply should be made in all cases where the source is in any degree open to the suspicion of impurity: and the water both from private and public sources should be examined. Where pollution is discovered, everything practicable should be done to prevent the pollution from continuing, or, if this object cannot be attained, to prevent the water from being drunk.

(*b.*) Simultaneously, there should be immediate thorough removal of every sort of house-refuse and other filth which has accumulated in neglected places; future accumulations of the same sort should be prevented; attention should be given to all defects of house-drains and sinks through which offensive smells are let into houses; thorough washing and lime-washing of uncleanly premises, especially of such as are densely occupied, should be practised again and again.

(*c.*) Disinfection should be very freely and very frequently employed in and round about houses, wherever there are receptacles or conduits of filth; wherever there is filth-sodden porous earth; wherever anything else, in or under or about the house, tends to make the atmosphere foul.

In the absence of permanent safeguards, no approach to security can be got without incessant cleansings and disinfections, or without extreme and constant vigilance against every possible contamination of drinking-water.

8. In view of any possibility that the infection of Cholera may again be present in this country, it is desirable that in each locality the public should ascertain to whom it practically has to look, in case of need, for its collective safety against such dangers as the above. The responsibility is, in a large proportion of cases, mixed. The most critical of all its branches, the responsibility of providing for the unpollutedness of water-supplies, is, in many very important places, in the hands of commercial companies; and it is to be hoped that these companies, informed, as they must be, of the calamitous influence which some of their number have exerted in previous epidemics of Cholera, will remember, if the disease shall again be present here, that each of them, in its daily distribution of water, has hundreds, or even thousands, of human lives in its hands. But, except to that extent, the responsibility for local defences against Cholera, both as regards water-supply and as regards local cleanliness and refuse-removal, is vested in the local Sanitary Authorities, Urban and Rural. These Authorities are all, by law, so constituted, as to represent, in their respective areas of jurisdiction, the will of the local rate-paying population; and each such population has had almost absolute means of deciding for itself whether the district which it inhabits should be wholesomely or unwholesomely kept. It is greatly to be wished that the former of these alternatives had, from long ago, been the desire of every local constituency in the country; and it may fairly be believed that, in considerable parts of the country, conditions favourable to the spread of Cholera are less abundant than at former times of visitation. But it is certain that in very many places the conditions of security are wholly or almost wholly absent; and it is to be hoped that in all this large class of cases, the Authorities, under present circumstances, will do everything which, in the remaining time, can be done, to justify the trust reposed in them by the Legislature for the protection of the public Health.

9. It is important for the Public very distinctly to remember that pains taken and costs incurred for the purposes to which this Memorandum refers cannot in any event be regarded as wasted trouble and

expense. The local conditions which would enable Cholera, if imported, to spread its infection in this country, are conditions which day by day, in the absence of Cholera, create and spread other diseases: diseases, which, as being never absent from the country, are, in the long run, far more destructive than Cholera: and the sanitary improvements which would justify a sense of security against any apprehended importation of Cholera would, to their extent, though Cholera should never re-appear in England, give amply remunerative results in the prevention of those other diseases.

John Simon,
Medical Officer of the Board.

Local Government Board,
July 5th, 1873.

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PUBLIC HEALTH.

REPORTS

OF

THE MEDICAL OFFICER OF THE PRIVY COUNCIL AND LOCAL GOVERNMENT BOARD.

NEW SERIES, No. II.

SUPPLEMENTARY REPORT TO THE LOCAL GOVERNMENT BOARD ON SOME RECENT INQUIRIES UNDER THE PUBLIC HEALTH ACT, 1858.

Presented to both Houses of Parliament by Command of Her Majesty.

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TO THE RIGHT HONORABLE THE PRESIDENT OF THE LOCAL GOVERNMENT BOARD.

SIR,

IN my recent Annual Report, when adverting to the list which I then submitted of inspections made under you by this Department during the year 1873, I stated that some of the cases had been of so much sanitary interest that I would, as soon as I could, bring them more particularly under your notice in a separate Supplementary Report.

My reference was especially to three very instructive outbreaks of Enteric or Typhoid Fever which had been investigated within the year: but I find that with them I can advantageously associate two other of our departmental cases which have had an exactly similar interest; and I accordingly beg leave to draw your attention to the subjoined reports of the Inspectors by whom the five outbreaks were investigated.

Enteric Fever, in regard of its mode of origin, seems to me the type of so vast a quantity of preventable disease as to claim, in an administrative point of view, the earliest and most vigilant attention of the Local Government Board. I therefore, at the opportunity of bringing the present special instances under your notice, and by way of preface to them, would submit to you some observations in which I have sought to embody the general experience of this Department with regard to Enteric Fever and the diseases which in preventability are most akin to it. I also annex, as of very valuable aid to the purpose of these observations, Mr. Netten Radcliffe's report of the results of a large inquiry, on which he has recently been engaged, with regard to that branch of local sanitary administration which is most concerned with the prevention of Enteric Fever.

I have the honor to be, Sir,
Your obedient Servant,
JOHN SIMON.

Medical Department;
July 29th, 1874.

MEDICAL OFFICER'S SUPPLEMENTARY REPORT.

FILTH-DISEASES AND THEIR PREVENTION.

I.

MEDICAL OFFICER'S REPORT.

1.—In the subject-matter of Preventive Medicine, considered with reference to the administrative needs of England at the present time, Enteric Fever, with the diseases which are allied to it in mode of origin, must necessarily, I think, stand as first topic: and I avail myself of this earliest opportunity to submit to the Local Government Board some observations on that class of diseases.

That very much disease is preventable, is the *raison d'être* of sanitary authorities.

2.—In my recent Annual Report, the vast amount of injury which is suffered day by day in this country through diseases well known to be preventable was referred to in regard of the responsibility which it imposes on all who have undertaken to serve in the new sanitary organisation of the country; and I submitted that "the Local Government Board, viewed as a Central Board " of Health, and the more than fifteen hundred District-Authorities " which, each with its Medical Officer of Health, locally admi- " nister the Health Laws, may be regarded as having had their " respective functions assigned to them in special and systematic " relation to that state of things."

Among the consequences of preventable disease, only the deaths can be counted.

3.—I do not pretend to give any exact statement of the total influence which preventable diseases exert against the efficiency and happiness of our population; for it is only so far as such diseases kill, and even thus far but very imperfectly, that the effect can be represented in numbers. Of the incalculable amount of physical suffering and disablement which they occasion, and of the sorrows and anxieties, the often permanent darkening of life, the straitened means of subsistence, the very frequent destitution and pauperism, which attend or follow such suffering, death-statistics, to which alone I can refer, testify only in sample or by suggestion.

Rough estimate of the mortality which is preventable:

4.—That the deaths which we in each year register in this country (now about half a million a year) are fully 125,000 more numerous than they would be if existing knowledge of the chief causes of diseases, as affecting masses of population, were reasonably well applied throughout England, is, I believe, the common conviction of persons who have studied the subject. The statistical considerations which in the first instance suggest that conclusion have so long and so admirably been put before the public in the successive Reports of the Registrar-General that I need but very briefly, and only by way of illustration, advert

to them. Looking at England as a whole, we see that of each 100 persons who die, not quite 10 have reached the standard old age of seventy-five years; and that of each 100 children born hardly 74 complete five years of life. We next see what appears to be a widely different expectation of life in different districts of the country: that while, for instance, in a considerable proportion (about a seventh of the number) of the districts into which England is divided for registration-purposes, the death-rate of infants in the first year of life, ranges from 8 to 12 per cent., there is a still larger proportion of districts in which it ranges even from 19 to 30; and that, under the influence of these Herodian districts the infant death-rate of England as a whole stands at the high average of 18. Similarly, taking the death-rate of the population at all ages living, we find that the present general English death-rate of about 22½ per 1,000 per annum, covers on the one hand local death-rates ranging from 13 to 17, and on the other hand local death-rates which range even to far above 30. Primâ facie, then, it would seem that influences hostile to life must be operating in parts of England far more vehemently than in other parts; and we turn to the registered "causes of death" to learn from them, if we can, under what peculiarities of local assessment life is so differently taxed or mulcted in the different parts of this one country. Here of course we have to proceed with caution; for alleged causes of death may be registered on very imperfect non-medical testimony; and even medical certificates (since rapidly growing knowledge cannot be equally distributed in a very large and wide-spread profession) may in variable proportions be so inexact or arbitrary in their naming of the causes of death as to be unavailable for comparisons in this respect. With due caution, however, cases of this sort can be set aside, or the fallacies which they would introduce be guarded against; and when, with such caution, different districts are compared in regard of the causes of death registered in them, this finer sort of comparison adds very greatly to the force of the rougher comparisons which were first made; for, so far as the register of "causes of death" can intelligibly answer us, it says that certain sorts of disease—and those just the sorts which we in other ways know to be the most preventable, are very greatly more fatal in some districts of England than in others. This statistical conclusion, as based on the local death-returns which are made to the Registrar-General, was to some extent indicated by Dr. William Farr more than 30 years ago in the earlier annual reports of the General Register Office, and was afterwards more fully established and discussed in an important paper by Dr. Greenhow which I had the honour of laying before the General Board of Health in 1858.*

* "Papers relating to the Sanitary State of the People of England: being the Results of an Inquiry into the different Proportions of Death produced by certain Diseases in different Districts in England; communicated to the General Board of Health by Edward Headlam Greenhow, M.D., with an Introductory Report by the Medical Officer of the Board on the Preventability of certain Kinds of Premature Death."

From the passing of the Public Health Act of that year, the unequal distribution of different diseases in England became matter for detailed medical investigation and advice under the Privy Council; and in proportion as particular districts have been medically inspected with regard to the prevalence in them of the particular diseases to which attention had been drawn, so has evidence become more and more complete, with regard to the dependence of vast annual excesses of disease and death on causes which in the most moderate sense may be called removable.

preventable, namely, under action of law.

The causes of disease to which I here refer as removable are exclusively such as contravene Public Hygiene: such, namely, as affect more or less in common the mode of life of masses of population, and such as in most, if not in all instances, are already understood to be under ban of law. Doubtless much disease is also produced, and much life consequently wasted, through causes which are within the province of Private Hygiene; causes, which either are not of massive operation, or may at least easily be escaped at individual option, and which the law does not, and generally could not, take within its scope; but to such causes I do not advert as removable in the sense of my present argument.

Of removable causes of disease, the chief is uncleanliness:

5.—Among causes which injuriously affect the Public Health of England, considered as a total, certain operate only in particular districts: as, for instance, some large adjacency of malarious or water-logged land, or some prevalent injurious industry: while others, though no doubt in widely different degrees, appear to be of general, perhaps nearly universal, operation. Foremost in the latter class, and constituting therefore in my opinion objects which claim earliest attention in the sanitary government of England, two gigantic evils stand conspicuous:—

first, the omission (whether through neglect or through want of skill) to make due removal of refuse-matters, solid and liquid, from inhabited places; and,

secondly, the licence which is permitted to cases of dangerous infectious disease to scatter abroad the seeds of their infection.

In certain very important cases, injury—immense injury, accruing to the public health, arises from a co-operation of these two evils: arises, namely, through the special facility which (as I shall presently illustrate) certain forms of local uncleanliness provide for the spreading of certain specific infections; and the influence which uncleanliness almost necessarily exerts in that way against the public health, make so large an addition to the influence which it exerts in other ways, that, in total power, uncleanliness must, I think, without doubt, be reckoned as the deadliest of our present removable causes of disease.

and particularly in the degrees which constitute Filth.

In stating this opinion of its fatal influence, I do not refer to it in its minor degrees, as compared with high standards of cleanliness or chemical purity, but refer chiefly to such degrees of it as fall, or ought to fall, within the designation of FILTH:—to

degrees, namely, which in most cases obviously, and in other cases under but slight mask, are such as any average man or woman should be disgusted at: such as, eminently, the presence of putrescent refuse-matter, solid and fluid, causing nuisance by its effluvia and soakage. Also in imputing to Filth, as thus illustrated, that its effluvia are largely productive of disease, I do not ignore that disease is also abundantly caused by air which is fouled in other ways. Particularly I do not forget the effluvia of overcrowding: that, within dwellings which are populated beyond their means of ventilation, the foulness of air, due to the non-removal of the volatile refuse of the human body, is as strictly within the physiologist's definition of Filth, and as truly a nuisance within the scope of sanitary law, as any non-removal of solid or liquid refuse: but for the purpose of my present observations, the question of overcrowding is something to be set aside as distinct, and the word "Filth" is therefore here used distinctively in that sense which suggests subject-matter for sewers and scavenging.

Old general knowledge of the hurtfulness of Filth.

6.—It has been among the oldest and most universal of medical experiences that populations, living amid Filth, and within direct reach of its polluting influence, succumb to various diseases which under opposite conditions are comparatively or absolutely unknown; and the broad knowledge that Filth makes Disease is amply represented in the oldest records which exist of legislation meant for masses of mankind. The exacter studies of modern times have further shewn that by various channels of indirect and clandestine influence (some of which I shall presently illustrate) Filth can operate far more subtly, and also far more widely and more destructively, than our forefathers conjectured. The later almost equally with the former knowledge, the finer almost equally with the more general, is indispensable for sanitary administration in modern times; and Filth is little likely to be guarded against with that thoroughness of detail which present science shows to be necessary, unless the detail follow some intelligent appreciation of the ways in which Filth becomes destructive. This more exact knowledge, though it owes its origin to medical observation, and will no doubt constantly be receiving additions from the same source, is such as at least all well-educated persons of the general public may be expected gradually to acquire and apply; and I believe that our newly instituted Medical Officers of Health will be rendering not their least service to the public, when they shall make their own possession of this branch of medical knowledge, and their consequent power of interpreting many obscure productions of disease, subservient to the education of the laity among whom they act.

Modern, more particular, knowledge of its modes of hurtful operation.

7.—An important suggestion of modern science with regard to the nature of the operations by which Filth, attacking the human body, is able to disorder or destroy it, is: that the chief morbific agencies in Filth are other than those chemically-identified stinking gaseous products of organic decomposition which force

themselves on popular attention. Exposure to the sufficiently concentrated fumes of organic decomposition (as for instance in an unventilated old cesspool or long-blocked sewer) may, no doubt, prove immediately fatal by reason of some large quantity of sulphide of ammonium, or other like poisonous and fœtid gas, which the sufferer suddenly inhales; and far smaller doses of these fœtid gases, as breathed with extreme dilution in ordinary stinking atmospheres, both give immediate headache and general discomfort to sensitive persons temporarily exposed to them, and also appear to keep in a somewhat vaguely depressed state of health many who habitually breathe them: but here, so far as we yet know, is the end of the potency of those stinking gases. While, however, thus far there is only the familiar case of the so-called *common chemical poison*, which hurts by instant action and in direct proportion to its palpable and ponderable dose, the other and far wider possibilities of mischief which we recognise in Filth are such as apparently must be attributed to *morbific ferments* or *contagia;* matters which not only are not gaseous, but on the contrary, so far as we know them, seem to have their essence, or an inseparable part of it, in certain solid elements which the microscope discovers in them: in living organisms, namely, which in their largest sizes are but very minute microscopical objects, and at their least sizes are probably unseen even with the microscope; organisms which, in virtue of their vitality, are indefinitely self-multiplying within their respective spheres of operation, and which therefore, as in contrast with common poisons, can develop indefinitely large ulterior effects from first doses which are indefinitely small. Of ferments thus characterised, the apparently essential factors of specific chemical processes, at least one sort—the ordinary septic ferment*—seems always to be present where putrefactive changes are in progress, as of course in all decaying animal refuse; while others, though certainly not essential to all such putridity, are in different degrees apt, and some of them little less than certain, to be frequent incidents of our ordinary refuse. As, apparently, it is by these various agencies (essential and incidental) that Filth produces "zymotic" disease, it is important not to confound them with the fœtid gases of organic decomposition; and the question, what infecting powers are prevalent in given atmospheres, should never be regarded as a mere question of stink. It is of the utmost practical importance to recognise in regard of Filth, that agents which destroy its stink may yet leave all its main powers of disease-production undiminished. Whether the ferments of disease, if they could be isolated in sufficient quantity, would prove themselves in any degree odorous, is a point on which no guess needs be hazarded; but it is certain that in doses in which they can fatally infect the human body they are infinitely out of reach of even the most

* For convenience I use the singular number, but have no intention of implying that ordinary putrefactive changes have only one ferment which can be considered habitual to them.

cultivated sense of smell, and that this sense (though its positive warnings are of indispensable sanitary service) is not able, except by indirect and quite insufficient perceptions, to warn us against risks of morbid infection. Even as regards the positive notices which we receive by the sense of smell with regard to putrefactive decomposition, we must not assume that the diffusion and potency of septic ferment in the air necessarily go pari passu with the diffusion and offensiveness of the fœtid gases:—Witness, on a very large scale, the experience of London in the summer of 1858; when, as persons who were then frequenting Westminster may well remember, our tidal river, enormously charged with decomposing sewage, stank week after week in a degree which excited much public alarm as to the possible consequences of the nuisance, and even led to an immediate interference of the Legislature;* but when, though the quantity of sulphuretted hydrogen in the river-atmosphere was such as rapidly to blacken the ordinary chemical test-papers, as well as to affect in the same way the lead-paint of vessels on the river, and was enough also to produce among persons much engaged on the river such signs of sulphide-poisoning as I have above mentioned, the particular ailments which attest the working of septic ferment on the human body were in even less than average prevalence among the unwilling subjects of this large experiment.†

Filth-ferments in their relation to air;

It must be remembered that gases on the one hand, and the particulate ferments on the other, stand in widely different relations to air and water as their respective media of diffusion. The ferments, so far as we know them, shew no power of active diffusion in dry air: diffusing in it only as they are passively wafted, and then probably, if the air be freely open, not carrying their vitality far: but, as moisture is their normal medium, currents of humid air (as from sewers and drains) can doubtless lift them in their full effectiveness, and, if into houses or confined exterior spaces, then with their chief chances of remaining effective: and ill-ventilated low-lying localities, if unclean as regards the removal of their refuse, may especially be expected to have these ferments present in their common atmosphere, as well as of course teeming in their soil and ground-water.

and to water.

Considerations like some which I have stated in regard of infective air apply equally to infective water. In the latter, just as in the former, the zymotic malignity is but indirectly and most imperfectly suggested to us by qualities which strike the common sense, or by matters which chemical analysis can specify. As any unbrutalised sense of smell will turn with disgust from certain airs, so will it, and common taste and sight, be repelled by certain waters; and as the chemist can shew certain foulnesses in the one, so he can shew certain foulnesses in the other; but these

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* See the word "speedily" in the preamble of the amending Metropolis Local Management Act, 21 & 22 Vict., c. 104.

† The particulars of this very interesting experience are given in my Second Annual Report to the Privy Council, pp. 54–6, in a paper for which I was indebted to Dr. Ord, now Senior Assistant Physician to St. Thomas's Hospital.

tests, it must always be remembered, are tests only of the most general kind. Confessedly they do not touch the *corpus delicti*, but only certain conditions to which it is or may be collateral; and their negative findings are consequently not entitled to the same sort of confidence as their positive. Chemical demonstration of unstable nitrogenous compounds in water is a warning which of course should never be disregarded: but till chemistry shall have learnt to identify the morbific ferments themselves, its competence to declare them absent in any given case must evidently be judged incomplete, and waters which chemical analysis would probably not condemn may certainly be carrying in them very fatal seeds of infection.

Excess of disease in filthy places not always due only to the Filth;

8.—Populations under the influence of Filth are in many cases suffering not only from that influence, but also from other removable causes of disease; and in any endeavour to estimate at all exactly, as for administrative judgment, the injury which is derived from Filth, evidently those additional influences should as far as practicable be made matter of separate account. In one case a filthy neighbourhood may be so poor that mere privation is an appreciable cause of disease in it. In another case, the population may be so badly housed in respects which by themselves would not be classed as Filth,—may be so overcrowded in their dwellings, or be inhabiting such close or ill-built quarters, that this has to be counted as causing disease. In a third case, some particular collective occupation, injurious to the adults and adolescents who follow it, may be creating disease additional to that which the Filth produces. In a fourth case, swarms of infants and young children, whose mothers are engaged away from home in some local industry, may be suffering disease from neglect and mismanagement: and so forth. And evidently if one would see what harm Filth can do in its own ways, one must discriminate it as far as possible from such concomitants as the above.

but notwithstanding mixed cases, the hurtfulness of the Filth is certain.

In filthy urban districts, where the foul air, comparatively incarcerated in courts and alleys and narrow streets, can act with most force in regard to masses of population, the population always shews an increased mortality under several titles of disease. Such miscellaneous increase of mortality affects probably all ages, more or less, but a distinctively large proportion of it attaches to the children. Apparently the mere influence of the Filth (apart from other influences) in such a district will be causing the infants and young children to die at twice or thrice or four-times their fair standard rate of mortality; and this disproportion, which becomes even more striking when the chief epidemics of ordinary childhood (measles and whooping-cough and scarlatina) are left out of the comparison, seems to mark the young lives as finer tests of foul air than are the elder and perhaps acclimatised population.

In trying to analyse the death-statistics of filthy districts, we soon find that, with regard to many of the separate elements in the miscellaneous mortality, we cannot argue in exact scientific terms: partly because very large quantities are registered under names

which have no definite nosological meaning,—e.g. "convulsions," "teething," "atrophy," "consumption"; partly also because some kinds which we can fairly identify by name (e.g. pneumonia) are such as we do not always ætiologically understand; and sometimes we may be only able to establish the broad fact that, within the area of Filth, the deaths, in total amount, are greatly more numerous than ought to be, and that the excess (or in mixed cases a certain share of the excess) can only be accounted for as the effect of the Filth. Though, when that broad conclusion is reached, more detailed conclusions may at first sight scarcely seem wanted for practical purposes, yet there is advantage in establishing the details of each case as exactly as the circumstances will allow; not only because it greatly concerns the progress of preventive medicine that all our attributions of cause and effect should be in the spirit of exact science, but also because in regard to filthy rural districts the argument from general death-rates would often be insufficient to carry conviction: and I therefore proceed to speak with some particularity of individual diseases which can be traced to Filth.*

Of diseases distinctively due to Filth, the most characteristic are the diarrhœal.

9. In all filthy districts, one particular class of diseases seems specially apt to stand in relief: the diseases, viz., which, in respect of their leading symptom, may be generalised as diarrhœal. These diseases, in their relation to Filth, deserve very special attention: first, on their own account, as extremely large causes of death; and secondly, because an exact knowledge of their method of production is likely to throw comparative light on the pathology of obscurer filth-diseases.

Common diarrhœa, and its relation to Filth.

A certain large quantity of endemic diarrhœa is medically spoken of as "common," in contrast with such so-called "specific" diarrhœal diseases as cholera and enteric fever. Perhaps in a certain sense all might equally claim to be called "specific:" since, no doubt, each distinct effect has essentially its own distinct cause: but at least provisionally the contrast of terms is convenient, because much "common" filth-produced diarrhœa (with perhaps much else of the miscellaneous mortality of the same districts) may reasonably be ascribed to infection with the "common" septic ferment which is an attribute of all filth. Among the effects which arise under experimental septic infections, as likewise in cases of accidental septicæmia in the human subject, acute catarrh of the mucous membrane of the intestines is an extremely prominent fact. The mucous membrane of the intestinal canal seems peculiarly to bear the stress of all accidental putridities which enter the blood. Whether they have been breathed or drunk or eaten, or sucked up

* I would note that, writing here on these diseases only for immediate practical purposes, I am obliged to leave unnoticed various of the more scientific aspects of the subject. As I must thus leave undiscussed the very interesting question of the influence of particular soils and seasons in favoring epidemics of Filth-Disease, I would the more especially refer to the very valuable and suggestive writings of Professor v. Pettenkofer, of Munich, on this branch of the study of Cholera and Enteric Fever.

into the bloodvessels from the surface of foul sores, or directly injected into bloodvessels by the physiological experimenter, there peculiarly the effect may be looked for: just as wine, however administered, would "get into the head," so the septic ferment, whencesoever it may have entered the blood, is apt to find its way thence to the bowels, and there, as universal result, to produce diarrhœa.

Enteric fever and its relation to excremental infection.

10.—It seems certain, however, that in the high diarrhœal mortality of filthy places, infections, of the sorts already recognised as "specific," exercise always a very great influence: and in the studies which have made a basis for the suggestions of preventive medicine in relation to Filth, none have hitherto been so instructive as the study of these "specific" filth-infections. To them I would now particularly advert; referring first to the disease which of late years has for sufficiently sad reasons become well known to the public of this country under the name of Enteric or Typhoid Fever.

Since the year 1849, when Dr. (now Sir William) Jenner made known his conclusive and masterly discrimination of this specific form of fever, successive studies have tended with singular uniformity to connect it in regard of its origin with nuisances of an excremental sort.* In illustration of that fact in the natural history of enteric fever, I may refer to an abstract which I append of the experience of the Medical Department during the four years 1870–3 in this particular branch of disease-production: and such illustrations might be multiplied to any desired extent. The experience is, not only that privies and privy-drainage, with their respective stinkings and soakings, and the pollutions of air and water which are thus produced, have in innumerable instances been the apparent causes of outbreaks of enteric fever, but, further, that they have seemed capable of doing this mischief in a doubly distinctive way: first, as though by some aptitude which other nuisances of organic decomposition, though perhaps equally offensive, have not seemed equally or nearly equally to possess; and secondly, as though this specific property, so often attaching to them in addition to their common septic unwholesomeness, were not, even in them, a fixed property. The explanation of this experience, the explanation of the frequent but not invariable tendency of privy-nuisances to infect with enteric fever, has seemed to consist in the liability of such nuisances to carry with them, not invariably, but as frequent accidental adjuncts, the "specific" contagium of any prevailing bowel-infection: for presumably the privies of a population receive (inter alia) the diarrhœal discharges of the sick; and it has long been matter of fair pathological presumption that in any "specific" diarrhœa (such as eminently is enteric fever) every discharge from

* The very able writings of Dr. Murchison, dating from a paper by him in the Medico-Chirurgical Transactions of 1858, have been of particular influence in that contention.

the bowels must teem with the contagium of the disease.* Medical knowledge in support of this presumption has of late been rapidly growing more positive and precise; and at the moment of my present writing I have the gratification of believing that under my Lords of the Council it has received an increase which may be of critical importance, in a discovery which seems to give us for the first time an ocular test of the contagium of enteric fever: in the discovery, namely, of microscopical forms, apparently of the lowest vegetable life, multiplying to innumerable swarms in the intestinal tissues of the sick, penetrating on the one hand from the mucous surface into the general system of the patient, and contributory on the other hand, with whatever infective power they represent, to the bowel-contents which have presently to pass forth from him.† Adverting then summarily, in an administrative point of view, to the present state of medical knowledge and opinion as to the way in which enteric fever spreads its infection in this country, I would say that it is difficult to conceive, in regard to any causation of disease in a civilised community, any physical picture more loathsome than that which is here suggested: that apparently, of all the diseases which are attributable to Filth, this, as an administrative scandal, may be proclaimed as the very type and quintessence: that, though sometimes by covert processes which I will hereafter explain, yet far oftener in the most glaring way, it apparently has an invariable source in that which of Filth is the filthiest: that apparently its infection runs its course, as with successive inoculations from man to man, by instrumentality of the molecules of excrement which man's filthiness lets mingle in his air and food and drink.

Cholera, and its relation to excremental infection.

11.—It seems certain that the distribution in England of an immense quantity of other specific disease must exactly follow that disgusting type. The local affinities of Asiatic Cholera, when present in this country, have always been so close to those of enteric fever, in respect of its association with circumstances of excremental filth, and the lines of pathological argument on this association (even apart from evidence which has been alleged on the direct communicability of cholera to the lower animals) are so parallel in the two cases, that no reasonable doubt can, I think, be entertained as to the substantial dependence of cholera-epidemics in this country on the opportunities which are ever widely open

* This is the argument of the late Dr. John Snow: which though urged by him more particularly in relation to Asiatic Cholera, was meant by him to have general application, and was expressly applied by him to enteric fever. In the latter relation it has from 17 years ago been constantly and very powerfully urged by Dr. Wm. Budd, of Clifton. From the beginning of our European experiences of cholera the doctrine of the specific infectiveness of the discharges in the disease had been argued by Dr. von Gietl of Munich, to explain, as he maintained, the atmospheric diffusion of the epidemic influence.

† This discovery (as I believe it to be) of the microphyte of enteric fever is the work of Dr. Klein, Assistant-Professor in the Brown Institution, and arose in one of the *Scientific Investigations in aid of Pathology and Medicine* which I have the honor of superintending under my Lords of the Council. The details of the subject are still undergoing investigation at Dr. Klein's hands.

for the above-described filthy method of infection. Indeed, with regard to the manner of spread of the entero-zymotic diseases generally, it deserves notice that the whole pathological argument which I am explaining grew among us in this country out of the very cogent facts which our cholera-epidemics specially supplied, and to which the late Dr. John Snow, twenty-five years ago, had the great merit of forcing medical attention: an attention at first quite incredulous, but which, at least for the last fifteen years, as facts have accumulated, has gradually been changing into conviction.

Similar relation of other diseases.

12.—The argument which applies to the bowel-discharges of Cholera and Enteric Fever, and which, in regard of them, rests on a very large quantity of detailed evidence, seems to extend by extremely strong analogy to every disease, whether nominally "common" or "specific," in which the human intestinal canal is the seat of infected changes: chiefly perhaps to such diarrhœal and dysenteric infections as are exclusively or distinctively intestinal, but likewise, I apprehend, more or less, to every general infection (such for instance as scarlatina) in proportion as it inclusively infects the bowels: and it would thus seem probable that air and water, having in them the taint of human excrement, must often carry with them, whithersoever they pass, the seeds of current morbid infections.

Powers of common septic infection to produce disease.

13.—But though hitherto, for convenience of argument, I have referred specially to the influence of human excrement in determining the spread of "specific" infections from man to man, and provisionally as if man's body were the sole birth-place of the several contagia which afflict his kind, assuredly that intermediary influence is but part, and it may be but a very subordinate part, of the faculty by which Filth produces disease. While it is indeed true as regards some contagia that at present we know them only as incidents of the human body, wherein we see them in case after case multiplying their respective types with a successivity as definite and identical as that of the highest orders of animal or vegetable life,—and while thus it is at present true, for instance, of smallpox or syphilis, that a case arising independently of a previous like case is hitherto practically as unknown to us as the parentless production of dog or cat, our knowledge with regard to other very important contagia is growing to be of larger scope. I would mention it as among the most hopeful advances of modern preventive medicine, that some diseases, which, in the sense of being able to continue their species from man to man, are apparently as "specific" as those which I have above-named, seem now beginning to confess in detail a birth-place exterior to man, a birth-place amid controllable conditions in the physical nature which is around us, a birth-place amid the "common," putrefactive changes of dead organic matter. Referring again now to what I have not pretended to be able to analyse in detail—the excess of miscellaneous, and in great part nominally "common," disease in filthy neighbour-

hoods, I would particularly wish to connect with that subject a reference to our growing scientific knowledge in the matter of the "common" septic ferment. The pathological studies of late years, including eminently certain very instructive researches which Professor Sanderson has conducted under my Lords of the Council, have clearly shewn that in the "common" septic ferment, or in some ferment or ferments not hitherto to be separated from it, there reside powers of disease-production as positive, though not hitherto as exactly defined, as those which reside in the variolous and syphilitic contagia. Experimentally we know of this ferment, that, when it is enabled by artificial inoculations to act in its most effective way on the animal body, and even more when it has received a curious increment of strength which its first propagation within the living body seems to bestow on it, it shews itself one of the most tremendous of zymotic poisons. It rapidly in the one animal body develops disease which then is communicable to another: febrile disease, with inflammations numerous and intense, and including in marked degree one of the acutest known forms of intestinal inflammation and flux: disease exactly corresponding to certain very fatal and unfortunately not infrequent infections to which lying-in women, and persons with accidental wounds and the wounds of surgical operations, are most subject, but which also sometimes occur independently of such exceptional states; infections, chiefly known under the names of erysipelas, pyæmia, septicæmia and puerperal fever; infections, which we sometimes see locally arising anew in unquestionable dependence on Filth, but of some of which, when arisen, it is perfectly well known that they are among the most communicable of diseases. And a further, perhaps still more instructive, teaching of the artificial infections is this: that the "common" ferment, which in its stronger actions quickly destroys life by septicæmia, can in slighter actions start in the infected body chronic processes which will eventuate in general tubercular disease. I need hardly point out that the above facts, extremely suggestive though they are, must of course, in relation to my main argument, be applied only under certain reserve; that evidently the exact conditions of the physiological experiment are not reproduced in ordinary life; and that against the common septic ferment, as presented in fouled atmosphere or fouled drinking water, the living human body in its normal state can apparently make considerable (though presumably not unlimited) resistance. But after all such reserves the truth remains, that, looking well at the pathology of human life under residence in foul air, we find ourselves again and again reminded of these results of physiological experiment: often seeing phthisis and other tubercular and like diseases gradually developed, as though under gradual overpowering of the limited normal resistance to the septic ferment; or seeing—and particularly where some exceptional bodily state (wounded or puerperal) gives opportunity, the sudden invasion of erysipelas or other septic infection, not in discoverable dependence on any human infectant, but conceivably a filth-

inoculation from the air.* The line of reflection thus suggested is one which I cannot now follow further, but of which the practical interest seems to be extremely great. For, while the excessive production of fatal disease in filthy neighbourhoods is a fact as to which there can be no doubt, and of which the immediate significance is deplorable, the ulterior suggestion is this: that so far as Filth in any instance produces anew such a disease as erysipelas or puerperal fever on the one hand, or phthisis or other tubercular disease on the other, the mischief first done is of a sort which entails certain possibilities of extension : such, namely, that in the one instance by accidental contagion, as in the other instance by hereditary transmission, it may, for aught we know, indefinitely extend beyond the sphere in which Filth first produced it.

II.

Forms in which Filth is found producing disease:

14.—Having in the above statements explained what I believe to be the present knowledge of my profession with regard to the diseases which Filth is apt to produce in the human body brought under its influence, and with regard therefore to the exact dangers which each prevalence of Filth implies, I now turn to the more administrative aspects of the matter, and may begin by referring to the chief forms in which Filth is apt to be about us.

Filth operating where it stands:

15.—There are houses, there are groups of houses, there are whole villages, there are considerable sections of towns, there are even entire and not small towns, where general slovenliness in everything which relates to the removal of refuse-matter, slovenliness which in very many cases amounts to utter bestiality of neglect, is the local habit: where, within or just outside each house, or in spaces common to many houses, lies for an indefinite time, undergoing fœtid decomposition, more or less of the putrefiable refuse which house-life, and some sorts of trade-life, produce: excrement of man and brute, and garbage of all sorts, and ponded slop-waters: sometimes lying bare on the common surface; sometimes unintentionally stored out of sight and recollection in drains or sewers which cannot carry them away; sometimes held in receptacles specially provided to favor accumulation, as privy-pits and other cesspools for excrement and slop-water, and so-called dust-bins receiving kitchen-refuse and other filth. And with this state of things, be it on large or on small scale, two chief sorts of danger to life arise: one, that volatile effluvia from the refuse pollute the surrounding air and everything which it contains; the other, that the liquid parts of the refuse pass by soakage or leakage into the surrounding soil, to mingle there of course in whatever water the soil yields, and in certain cases thus to occasion the deadliest pollution of wells and springs. To a really immense

* See in Sixth Report to the Privy Council, pp. 58-64, observations on the so-called "traumatic infections" in their relations to Hospital Hygiene.

extent, to an extent indeed which persons unpractised in sanitary inspection could scarcely find themselves able to imagine, dangers of these two sorts are prevailing throughout the length and breadth of this country, not only in their slighter degrees, but in degrees which are gross and scandalous and very often, I repeat, truly bestial. And I state all this in unequivocal language, because I feel that, if the new sanitary organisation of the country is to fulfil its purpose, the administrators, local and central, must begin by fully recognising the real state of the case, and with consciousness that in many instances they will have to introduce for the first time, as into savage life, the rudiments of sanitary civilisation.

Filth operating at a distance.

16.—A second point, which equally with the above needs to be recognised by all who are responsible for the prevention of Filth-Diseases, is: that Filth does not only infect where it stands, but can transmit its infective power afar by certain appropriate channels of conveyance; that, for instance, houses which have unguarded drainage-communication with cesspools or sewers may receive through such communication the same filth-infections as if excrement stood rotting within their walls; and that public or private water-reservoirs or water-conduits, giving accidental admission to filth, will carry the infection of the filth whithersoever their outflow reaches. Thus it has again and again happened that an individual house, with every apparent cleanliness and luxury, has received the contagium of enteric fever through some one unguarded drain-inlet; or that numbers of such houses have simultaneously received the infection, as an epidemic, in places where the drain-inlets in general have been subject to undue air-pressure from within the sewer. And thus equally on the other hand it has again and again happened that households, while themselves without sanitary reproach, have received the contagium of enteric fever through some nastiness affecting (perhaps at a considerable distance) the common water-supply of the district in which they are.*

Chief sources of excremental infection illustrated.

17.—When an epidemic of enteric fever, or of cholera or diarrhœa, has been traced (as in general it quite easily can be) to some gross excremental pollution of air or water, the primary source of such pollution will usually be under one or more of the following three heads, viz.—faults of public sewerage, faults of indoor water-closets and other apparatus of house-drainage, and the fault of bog-privies.

* For illustrations how the infection of houses with Filth-diseases (and specially with enteric fever) is promoted by imperfect ventilation of sewers, I may refer to the case of Windsor, which I gave in my first Annual Report to the Privy Council, p. 16, or to the cases of Croydon and Worthing which Dr. Buchanan describes in appendix to my Ninth Report, pp. 103 and 195: and of course these illustrations of infection on an epidemic scale would apply à fortiori to individual cases where the drain-inlets of houses are left untrapped. To illustrate the relations of polluted public water-supplies to the dissemination of cholera and enteric fever, I may refer to the collection of cases which I gave in my Twelfth Report.

18.—The public sewerage may be at fault in either of two ways: first, in absence of sewers, so that slop-waters and other liquid filth, if not disposed of on the private premises, have to pass without proper tubular conveyance along public ways, either free on the general surface, or in open and generally very irregular channels meant only for rain-water, where necessarily they must more or less stagnate and stink and soak: secondly, in the existence of sewers which in themselves are more or less mischievous.

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(1.) In regard of sewerage;

With regard to non-provision of sewers in inhabited areas, apparently there often is an assumption that sewers may properly be dispensed with in cases where water-closets are not in use; that sewers (*i.e.* public drains of tubular type) are only wanted where the intention is to convey privy-refuse; and that, for the mere slop-waters of the population, the open way-side gutters which are meant for rain-water will suffice. This assumption can only rest on ignorance of what "slop-waters" really are, in respect of the filth which is contained in them; and its wrongness is sufficiently evident to anyone who observes how extremely offensive are in general such wayside gutters as are allowed to receive liquid refuse from groups of houses. Such refuse at its worst is a very condensed form of sewage, and even at its best is such as cannot without nuisance be let loiter and soak by the way-side. As soon as the point is passed at which houses can be expected to dispose of their own liquid refuse on their own ground, the point is reached at which proper public channels for the conveyance of such refuse should be provided; and the irregular way-side channels which may perhaps quite properly suffice for rain-fall, cannot, I apprehend, in relation to slop-waters, be deemed such "sufficient sewers" as the law requiries local authorities to provide.

(a.) want of sewers;

Demerits in existing sewers can in some essential respects be judged by common observation. As the object of a sewer's existence is to prevent the stagnation of filth in and about houses and frequented places, and to guard against the dangerous pollution of air and soil which the filth, if not effectually conveyed away, must occasion, so, of course, any sewer which itself occasions any such stagnation and pollution is (in proportion as it does so) unsuccessful; and a sewer which stinks at its open gratings is, pro tanto, giving evidence of such unsuccess. The indispensable conditions of success in a sewer are, first that the flow of sewage to its outfall shall be, as perfectly as possible, continuous and complete and scouring, not ponded and leaking and depositing; and secondly, that the sewer shall have perfect ventilation. A sewer in which these conditions are fulfilled will scarcely, if at all, under ordinary circumstances, cause appreciable odor at open (untrapped) gullies in the street; the air in it, if at times compressed, will not easily exert at the duly guarded inlets of house-drains any such pressure as can make way for it into houses; and in cases where accidental defects of house-drains unfortunately permit sewer-air to enter houses, the sewer-air will be at its lowest degree of dangerousness. It is a great security for such perfect

(b.) faults in sewers;

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ventilation of sewers as is essential to the safety of houses, that, in addition to whatever special ventilating-shafts are provided, street-gullies should as far as practicable be left untrapped: and complaint of nuisance from any such gullies should not necessarily be taken as reason for trapping them. In case of such complaint, the presumption is that from original ill-construction or some other cause the sewer does not properly fulfil its object, but has filth accumulated and stagnant in it as in a cesspool, and has its ventilation at least relatively in defect; and the nuisance which such a sewer occasions in the public way, is far less important than the risk incurred by the inhabitants of houses which drain into the sewer. Merely to trap street-gullies in any such case would be greatly to increase the danger to houses; the use of charcoal trays in gullies, in the hope to disinfect their effluvia, has repeatedly proved dangerous in the same way: and I accordingly think it an essential principle, that the evil of a stinking sewer should always be dealt with at its root. Thus, a sewer which is imperfectly ventilated should have perfect ventilation provided for it; a sewer which, though fairly constructed, is from poorness of current not completely self-scouring, should at due intervals have extrinsic flushing: and sewers which, with radical ill-construction, are virtually but cesspools under the street, should without delay be abolished.

(2.) in regard of house-drainage and water-closets;

19.—Secondly, a very large danger to the public health, and particularly to the better-off classes of society, has of late years consisted in the recklessness with which house-drains, receiving pipes from water-closets, sinks, cisterns, baths, &c., in the interior of houses, and often actually within bedrooms or the adjoining dressing-rooms, have been brought into communication with sewers. Among architects and builders there seems to have been very imperfect recognition of the danger which this arrangement must involve, in event either of unskilful first construction or of subsequent mismanagement or want of repair. Then, in regard of construction, an almost unlimited trust has been placed in artisans who not only could hardly be expected to understand certain of the finer conditions (as to atmospheric pressure) which they had to meet, but who also in not a few instances have evidently failed to apprehend that even their mechanical work requires conscientious execution. Under influence of the latter deficiency there have been left in innumerable cases all sorts of escape-holes for sewer-effluvia into houses, and disjointed drains effusing their filth into basements: while under the other deficiency, house-drainage, though done with good workmanlike intention, has often, for want of skilled guidance, been left entirely without exterior ventilation, and sometimes has in addition had the over-flow pipes of baths or cisterns acting as sewer-ventilators into the house: and all this not infrequently in places where the sewer itself, from which so much air has been invited, has been an ill-conditioned and unventilated sort of cesspool. It is almost superfluous to say that under circumstances of

this sort a large quantity of enteric fever has been ensured; and I should suppose that also a very large quantity of other filth-disease must have sprung from the same cause. Then there has been the vast quantity of interior air-fouling which arises from mismanagement of drain-inlets, or from non-repair of worn-out apparatus: as when sink-traps, injudiciously made moveable, have been set aside; or when pipes under temporary disuse, having evaporated all water from their traps, or leaden closet-pipes, with holes corroded in them, have been left fouling the house with a continuous eructation of sewer-air.* Again, in poor neighbourhoods, water-closets have in many cases been constructed with scanty and ill-arranged water-service to flush them, or have even been left to only such flushing as the slop-water of the house, or other water thrown in by hand, might give: and again and again these ill-watered and often obstructed closets have been found acting on a large scale as causes of disease. Again, a different sort of danger, and one which seems capable of wide operation, has been seen to arise where water-closets receive their flushing-service from the mains of a so-called "constant" supply: for supplies called constant must not only sometimes intermit for purposes of necessary repair, but also in some cases are habitually cut off during the hours of night; and the danger is that, during times of intermission, if there be not service-boxes or cisterns between the privy-taps and the mains, privy-effluvia and even in some cases fluid filth will be (so to speak) sucked from closet-pans into water-pipes. This danger, which hitherto has been little known to the public, but which it is important to have well understood, is illustrated by two remarkable reports which I subjoin, respectively by Dr. Blaxall and Dr. Buchanan, on outbreaks of enteric fever thus occasioned. Dr. Blaxall's report (App. No. 2) is of particular interest, as it represents, I believe, our first departmental discovery of this cause of disease in actual operation; † and Dr. Buchanan's (App. No. 3) seems to me of remarkable value, not only as being in itself a model of exact ætiological inquiry, but as illustrating the filth-causation of enteric fever, clandestinely effected, under circumstances where primâ facie any filth-disease would have seemed impossible.

(3.) in regard of accumulative privies.

20.—Thirdly, while it cannot be denied that ill-devised and ill-managed water-closets and their accompaniments have caused (and particularly among the better-off classes of society) filth-diseases to a very large extent, a far larger range of mischief throughout

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* Dr. Andrew Fergus of Glasgow in papers of much sanitary interest contributed by him to the Edinburgh Medical Journal (February 1872 and February 1874) adduces evidence to show that the ordinary corrosion of leaden pipes from closets and sinks is a chemical effect of sewer-air, and that it goes on with greatly increased rapidity in cases where the pipes are unventilated.

† I am glad to note, as corroboration from a source which I highly esteem, that, while Dr. Blaxall was recording the observations which he had made at Sherborne in evidence of the above mode of production of enteric fever, Dr. Alfred Carpenter of Croydon was recording independent observations which he had made in that town to the same effect. See "Public Health," July, 1873.

England has attached to the other kinds of privy-arrangement: and of all the filth-influences which prevail against human life in this country, privies of the accumulative sort operate undoubtedly to far the largest extent.

By what standard should they be judged?

The intention and, where realised, the distinctive merit of a system of water-closets is, that in removing excremental matters from a house it does so with perfect promptitude, and in a perfectly neat and complete manner, not having any intervals of delay, nor leaving any residue of filth, nor diffusing any during its operation; and where the water-system is not in use, these objects ought still as far as possible to be secured. Thus, in the absence of water-closets, evidently any reasonable alternative system ought to include the following two factors, brought into thoroughly good mutual adjustment: first, proper catchment-apparatus in privies; and secondly, proper arrangements for privy-scavenage. The essential conditions of a proper catchment-apparatus are that it, as well as all adjacent underworks of the privy, shall as far as practicable be unabsorbent; that it shall absolutely preclude soakage or leakage of filth into soil or buildings or water; that it shall not admit rainfall or slop-waters; that it shall be so limited in size as not to allow of any needlessly offensive accumulations of matter; and that, whether moveable or fixed, it shall easily admit of thorough cleansing. The essential conditions of proper privy-scavenging are, that it shall be strictly methodical; that from beginning to end it shall be so conducted as to occasion the least possible nuisance, public or private; that its performance shall be at such short intervals as invariably to precede the putrefaction of the excrement; and that there shall be associated with it all such acts of thorough cleansing as the catchment-apparatus and other underworks of the privies may require. Further, in order that the fulfilment of these conditions may be possible, it is essential that the location and approaches of the privy should be definitely adapted to acts of scavenage.

Their actual relation to that standard.

Now, hitherto, in places not having water-closets, the general practice has flagrantly contravened those conditions. Either it has had no other catchment-apparatus than the bare earth beneath the privy-seat, and has trusted that this (receiving the excrements and often also the house-slops on to its natural surface or into a hole dug into it) would absorb and drain away the fluid filth, and serve during months and years as heaping-place for the remainder; or else it has had, as supplement to the privy, a large enclosed midden-stead or cesspool, partly or entirely of brickwork or masonry, intended to retain large accumulations of at least the solid filth, with or without the ashes and other dry refuse of the house, and in general dividing its fluid between an escape-channel, specially provided, and such soakage and leakage in other directions as the construction has undesignedly or designedly almost always permitted. Privies, such as these, have not been meant to have their filth removed except when its mere largeness of bulk (exceeding or threatening to exceed the limits of the privy-pit or cesspool or midden) might mechanically make

removal necessary, or else when there might happen to arise an agricultural opportunity for the stuff; and public scavenging in relation to such privies has either had no existence, or has been adapted to the supposition of an indefinite local tolerance of accumulation. All this accumulation, with its attendant exhalation and soakage, and at intervals the shovelling and carting away of its masses of fœtid refuse, and the exposure of the filth-sodden catchment-surfaces of privy-pits and middens, has been, as needs hardly be said, an extreme nuisance to those in whose vicinity it has been; and sometimes with the aggravating condition that, because of the situation of the privy, each filth-removal must be through the inhabited house. What nuisance this system at present constitutes in innumerable populous places, including some of our largest towns, can indeed hardly be conceived by persons who do not know it in operation; and the infective pollutions of air and water-supply, which it occasions to an immense extent in towns and villages throughout the country, are chief means of spreading in such places some of the most fatal of filth-diseases.

21.—Such are the three heads, under one or more of which will commonly be found the true explanation of outbreaks and prevalences of entero-zymotic disease in the different districts of this country; and outbreaks which from time to time have arisen in seeming dissociation from such causes as I describe have again and again, under minute examination, resolved themselves into new illustrations of the general rule. For administrative reasons it is highly important that cases which seem exceptional should be thoroughly studied; and especially as regards enteric fever (because it apparently obeys so very sharply defined a rule of causation) I would advocate the strictest scrutiny of any origination which may seem not to have been excremental. Present knowledge seems very positively to say that the degree and extent in which enteric fever shall remain unexterminated from England will express the degree and extent in which sanitary administration shall have failed in rudimentary duties; and since, in particular local applications of this test, the prevalence of enteric fever in any district will primâ facie impugn the sufficiency of the local administration, it becomes of the more importance that the habits of the disease should be well understood, and that every mystification of unexplained facts should as far as possible be removed. An unexplained outbreak of enteric fever will sometimes mean (as in the very instructive case reported in my App. No. 5.) that the locality where the disease occurs has had in it, as its own local property, some curiously unsuspected liability to filth-infection: but on the other hand there are circumstances under which the excremental nuisance of one district may exceptionally do its mischief in another. This possibility might of course be illustrated by any such conductions of filth as I have noted in a former passage of these observations; but I wish here to draw particular attention to the possibility, now well-established, of filth-infection being transmitted even on a large scale from district

Excremental infection which has caused disease may require careful search to expose it:

as in case reported in App. No. 5;

and in various epidemics produced by infected milk supply.

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to district in particular articles of food, and especially in the article of milk. In 1870, Dr. Ballard, now of this Department, but who at that time was working with high character as Officer of Health for the parish of Islington, was able to shew that an outbreak of enteric fever, which had attacked in ten weeks 70 families and 175 persons in part of his district, coincided with the use of milk supplied from a particular dairy, where shortly before the outbreak there had been cases of enteric fever, and where apparently the infected house-drainage must have had easy access to an underground water-tank on the premises. There could be little reasonable doubt as to what in this epidemic had been the infectant; and since Dr. Ballard's connexion with this Department it has twice happened to him to be able very clearly to trace the same method of infection at work in considerable outbreaks of enteric fever which he has been investigating; one in 1872 at Armley in the borough of Leeds, the other in 1873 at Moseley and Balsall Heath near Birmingham. A like case on a very large scale, and in some respects of unique interest, occurred also last year in London, chiefly in and about Marylebone, and was investigated elaborately by Mr. Netten Radcliffe, assisted in some stages of the inquiry by Mr. Power. A special interest of this case, as regards the point to which I have been adverting, is that here a great outbreak of enteric fever occurred at a distance of forty or fifty miles from the sanitary jurisdiction in which its true cause was contained; and the case is of the more value because the outbreak, as it happened to be in London, and happened also to have struck at its first blow in the houses of more than a dozen physicians and surgeons, had from the first its circumstances very attentively noticed by an unusual number of competent observers deeply interested in a right knowledge of them. I subjoin (App. Nos. 4–6) the instructive reports which relate to these three epidemics of enteric fever, respectively referable to supplies of milk. There is in each case every reason to believe that the epidemic was due to excremental pollution of the dairyman's well; and it is solely in that point of view that I here insist on the cases. How the dairyman's water was enabled to spread its influence to his milk, and by what proportionate admixture it did so, are questions of little importance to my present subject-matter. The essential point is, that the water with which a dairyman washes his pails, and of which a very variable quantity may under varying circumstances remain in them as an addition to his milk, is not likely to be of better quality than that which he and his local sanitary authority consider good enough for his own drinking; and that, in regard of this and many like possibilities of casual filth-infection, the general public are in intimate sanitary partnership with various of their purveyors of food.

III.

To prevent Filth-Diseases, Filth must be prevented.

22. In order to the prevention of Filth-Diseases, the prevention of Filth is indispensable. Truism though this may seem, I think

Disinfectants can only give a very subordinate assistance.

it needs to be expressly insisted on, as against any belief that districts, allowed to become filthy, can off-hand be made wholesome by disinfectants. To chemically disinfect (in the true sense of that word) the filth of any neglected district, to follow the body and branchings of the filth with really effective chemical treatment, to thoroughly destroy or counteract it in muck-heaps and cesspools, and ashpits, and sewers, and drains, and where soaking into wells, and where exhaling into houses, cannot, I apprehend, be proposed as physically possible; and the utmost which disinfection can do in this sense is apparently not likely to be more than in a certain class of cases (see § 39) to contribute something collateral and supplementary to efforts which mainly must be of the other sort. This opinion, as to the very limited degree in which chemistry can prevail against arrears of uncleanliness, does not at all discredit the appeals which are constantly and very properly made to chemistry for help in a quite different sphere of operation; with regard, namely, to the management of individual cases of infectious disease, and to the immediate disinfection of everything which comes from them.* In this latter use of disinfectants, everything turns on the accuracy and completeness with which each prescribed performance is done; but such accuracy and completeness are of course only to be ensured where operations are within well-defined and narrow limits; and in proportion as disinfection pretends to work on indefinite quantities or in indefinite spaces, it ceases to have that practical meaning. Again and again in the experience of this department a district has been found under some terrible visitation of enteric fever, from filth-infection operating through house drains or water-supply; but with the local authority inactive as to the true cause of the mischief, and only bent on practising about the place, under name of disinfection, some futile ceremony of vague chemical libations or powderings. Conduct such as this, referring apparently rather to some mythical "epidemic influence" than to the known causes of disease, and savouring rather of superstitious observance than of rational recourse to chemistry, is

* As regards certain procedures on a small scale, we know that, with well-circumscribed matter to work upon, and with chemical action precisely adjusted to its task, we can absolutely kill any given contagium. Taking, for instance, a bit of glass which has on it a charge of vaccine or variolous matter, we know that, if we *sufficiently* heat it in the flame of a lamp, or *sufficiently* treat it with certain strong officinal chemicals which act in a like manner, we annihilate the power of infection; and we know that, in the sick-room where lies a patient with any dangerous infectious disease—say diphtheria, small-pox, or enteric fever, we can to some extent imitate the above acts. Provided that real skill shall direct, and real conscientiousness shall execute, what has to be done, every tangible discharge which passes from the patient, every sheet or towel or handkerchief which any discharge from him has fouled, can be treated with heat or other disinfectant in a way to give at least comparative security against any outward spreading of his infection. It is greatly to be hoped that, with time and with progress of general education, the systematic doing of such acts as these will in each sick-house be considered an imperative duty of good citizenship, and may at last be so fully understood in that light as to be made, as far as practicable, an obligation at law: for disinfection in that sense (however remote we may now be from any sufficient adoption of it) would undoubtedly, if adopted, make chemistry an important ally to cleanliness in combating the filth-diseases of England; but such disinfection, the whole value of which is in its precision, differs diametrically from the pretended district-disinfections to which my text refers.

eminently not that by which filth-diseases can be prevented; and, contrasting it therefore with means by which that result can be secured, I would here specially note a warning against it.

The essential preventive is cleanliness;

23.—In order to reduce that vast quantity of preventable disease which has its type in enteric fever, and in relation to which each individual case of enteric fever which occurs ought to be regarded as having an important local significance, the one essential condition is CLEANLINESS. That local sanitary authorities, proceeding to act upon this principle, with a clear intelligence of what cleanliness really means, and with sincere resolution to enforce it in their respective districts, can within a few years reduce by some tens of thousands the annual mortality of England, is, I think, at least as certain as that such ought to be the aim of their existence.

in the highest degree in which it can be attained.

24.—The perfection of cleanliness would be that all refuse-matters should from their very beginning pass away inoffensively and continuously: and the principles of approximation to that ideal must evidently be, first to provide to the largest practicable extent for the continuous outflow of refuse as fast as produced, and secondly (so far as continuous outflow cannot be got) to provide for the closest possible limitation and the completest possible innocuousness of such refuse as is unavoidably detained. Rules like these present themselves as mere transcripts from Nature to those who know as physiologists how the animal body, in its individual working, deals with the refuse of its own vital actions: and the individual body, hindered in its respiration or other excretory acts, may serve to picture the inevitable unhealthiness of any community, whether large or small, which lets its decaying refuse-matters gather about it.

Cleanliness not possible for communities, except with method and organization for certain collective services.

25.—Wherever human beings are settled for residence, the cleanliness which is indispensable for healthy life can only be secured by strict method. Even where houses stand single and with wide space around them, the householder cannot safely neglect that sanitary obligation in regard of the refuse of his one household: the slop-waters, the cooking-waste, the various house-sweepings, the human fæces and urine, the excrements of domestic animals, &c.: and the obligation becomes more and more important in proportion as dwellings are gathered together on comparatively small areas.

The law does not allow any holder of premises, whether in town or country, to neglect that obligation to any injurious extent; and it is the express intention of the law that each local Sanitary Authority, rural or urban, should in its respective district see strictly to the enforcement of the obligation, and give all proper aid to its due fulfilment. Each Authority is bound by law to see that the drains, waterclosets, privies, and ash-pits in its district are so constructed and kept as not to be a nuisance: and with reference to these and various other matters of concern to health, each Authority is bound by law to make from time to time (either by itself or its officers) inspection of its district for the purpose of ascertaining what

nuisances exist calling for abatement under the provisions of the Nuisances Removal Act, and the Authority must enforce those provisions against the nuisances. In order that residents may have necessary common facilities for disposing of their refuse, the Authorities are bound by law to make such sewers as may be necessary for effectually cleansing and draining their districts: and they may either themselves undertake or contract for the removal of refuse from premises and the cleansing of privies, ashpits, and cesspools, or may make bye-laws imposing these duties upon the occupiers of the premises.

In the detailed application of the law different districts and parts of districts require, at the hands of their Authorities, a management graduated according to circumstances: certain circumstances requiring only the general supervision of the Authority, while others require, in higher and higher degrees, that the Authority should itself intervene and operate. The holder of outlying rural premises, will generally be able to consume his own refuse-matters satisfactorily on his own or some closely adjacent land: and the sanitary Authority, in regard of such cases, has only to make sure that the essential objects of the Nuisances Removal law are attained. Even here, however, it will always be requisite to see, as regards labourers' cottages and other like cases, that refuse is not thrown or accumulated in situations where its effluvia or soakings can be offensive or injurious; and the relation of privies, piggeries, cattle-stalls and dung-heaps, and of their several outflows, to the walls of dwellings and to sources of water-supply, must always be cautiously observed. In proportion as dwellings are aggregated, and populations increase, in villages, towns, and cities, it becomes more and more difficult for refuse to be properly disposed of by the separate action of individual householders. In very early stages of such aggregation, the Authority finds itself called upon to provide common sewers for the joint liquid refuse of the localities, and more or less common scavenging, not only for the public ways but in aid of the defæcation of private premises; and these collective services require to be more and more developed in proportion as populations become more and more urban. In proportion as such facilities are not given, more and more vigilance is wanted under §20 of the Sanitary Act, 1866, to see that nuisance do not arise from individual mismanagement of house-refuse,—that, in places unprovided with sewers nuisance be not caused by slop-water,—that, in places where water-closets are impossible, nuisance from bad privy-management do not exist,—that, in places to which scavenging does not extend, nuisance from filth-accumulation do not arise on individual premises. On the other hand, with the growth of the collective services, the Authority more and more finds that (greatly to the advantage of the public health) it has become the preventer rather than the remover of nuisances; and so universally is this the fact that, bearing it in mind, Sanitary Authorities, when proceeding to think systematically of their duties, will generally find it advantageous to regard the prevention rather than the removal of nuisances as their main administrative problem.

Removal of refuse has two main divisions: sewerage and scavenage.

26. Sewerage and scavenage between them have to do all the work of each Local Authority in carrying off the refuse of the district: the privy-refuse, the ashpit-refuse, the slop-waters, and in certain cases trade-refuse and the refuse of domestic animals. Sewerage and scavenage—assisted, as regards the matters which are within their range, by proper bye-laws, and supplemented, as regards the matters which are outside their range, by proper enforcement of the law against nuisances,—they, thus assisted and supplemented, and of course with adequate supply of water, are the two essential agencies of all local cleanliness. In proceeding to settle any scheme for their local application, the question first to be decided is, which of the two is to deal with privy-refuse; but whichever way this decision is to go, a clear view must always be had as to the eventual disposal of both sorts of refuse.

All disposal of refuse-matters must be so managed as not to make nuisance.

27.—All Local Authorities collecting refuse-matters, whether by sewerage or by scavenging, have of course to dispose of them in ways which shall not cause, or shall cause as little as possible, any nuisance in relation either to air or water: and this (sometimes difficult) obligation is at present urging itself on the notice of many Local Authorities as virtually a new problem with regard to the outfalls of liquid refuse. The obligation, not to cause nuisance by sewage outfalls, exists in an infinite range of magnitudes: from the vast sewage-tunnels of London on the one hand to the little village-sewer and its occasional flushings on the other; but, whether as to village slop-waters or to great urban sewage-floods, equally it has to be provided that no avoidable atmospheric nuisance shall be produced by the outfall, and that all natural water-courses (or at least all such as may be giving domestic supplies) shall be protected as far as practicable from pollution. Along the coast-line of England there may be cases in which those conditions will be most conveniently and cheaply attained by letting the sewage run as mere waste (subject to such precautions and with such engineering arrangements as may be necessary) into river-estuaries or into the sea: but this course, in the cases where it is possible, is not by any means necessarily to be preferred: for sewage contains the essential elements of fertilisation for land, and land ought always to be considered its proper destination except where from particular local circumstances this use of it would involve too much cost to be profitable. In the large majority of cases throughout England an option of entirely wasting sewage as above does not exist: on the contrary, the obligation not to cause nuisance by sewage-outfalls will be found in general to involve as its consequence that the sewage must be purified by land; which generally will in return by increased fertility yield more or less pecuniary set-off against the cost of such constructions and service as the use of that method of sewage-disinfection may require. Evidently, then, the management of sewage-outfalls is a matter for serious consideration by Local Authorities: so that on the one hand each inhabited area may best eliminate every sort of fluid refuse

which it produces, and that, on the other hand, the required prevention of outfall-nuisances may be economically as well as effectually attained. To improve public knowledge on the means of attaining those objects has for many past years been the object of continuous elaborate study under successive Royal Commissions; and it is to be desired that all persons who have to deal responsibly with the disposal of refuse-matters should be acquainted with the practical conclusions to which that study has led, as particularly represented in the very valuable reports of the Rivers Pollution Commission, 1868.

Disinfection of sewage.

28.—As regards means for disinfecting sewage the Commission reports that purification in such degree that the outflow may properly be allowed to pass into the running waters of the country, can be got under certain conditions by the action of land upon the sewage, but not in any other practicable way; and that, in order to the required action of land on sewage, two methods are available: the method by *agricultural irrigation* and the method by *intermittent filtration*.

Of these two methods neither can in practice be so applied as not to include some participation of the other: for filtering beds have of course more or less irrigated surface, and irrigated fields have of course more or less downward filtration: but, except so far as there is this accidental overlapping, the methods contrast with each other in respect of the natural forces to which they chiefly appeal; and, while they both effect the purification of sewage, their collateral results are widely different. The irrigation-method bases itself on the *appropriative* action which a certain surface of cultivated land with growing crops on it exerts over organic matters supplied to it as manure: the case for it exists in proportion as there is suitable land in the comparatively large extent which suffices to utilise to the utmost the fertilising power of sewage: and the intention is that this land, while disinfecting the sewage, shall also yield adequate pecuniary return in irrigated crops. The filtration-method, on the contrary, bases itself on the *destructive* influence which a certain cubic quantity of well-aerated porous earth, receiving organic matters at intervals on its surface, and discharging them below, will exert on them as they gradually sink (followed again by air) through its thickness: it requires plots of suitably-placed porous land, deeply under-drained, to be used in rotation as disinfecting-ground for the sewage delivered on to them; and the method is such that, though more or less vegetable produce may be obtained from the comparatively small area of land which suffices for these filtration-plots, the fertilising powers of the sewage are of necessity in great part sacrificed.

In view of the sanitary intention of these processes, Local Authorities adopting either of them must, of course, see that it effects its proposed action completely, and that it does not cause any nuisance of its own. In choosing localities for irrigation or filtration, in designing the works for either purpose, and in the

day-by-day management of such works, every possible care must be taken that all populations within range of influence of the works shall be safe from injury, whether through air or through water; and as regards the latter, it must be particularly cared for that the quantity of land, and the details of the application of sewage to it, shall be such as will, under all variations of seasons and weather, always effectually purify the sewage before it can have access to any watercourse. The standard of the Rivers Pollution Commission, on the presumption that 'rivers are not to supply drinking-water, is, that irrigation-land at the rate of at least an acre for every 100 of the population, or filtration-land at the rate of an acre for every 3,000 of the population, will give to sewage such degree of purification as to justify its being allowed to pass into rivers; but with what least quantity of land (properly used) the purification of sewage will be so complete that the outflow of the land shall be safe drinking-water, is a question which has yet to be answered by local experiences.

Limits of the utility of sewers, as regards what must, and what may be conveyed by them.

29.—Among the conclusions of the Commission, there are two which may particularly assist the judgment of Local Authorities as to getting full use of sewerage in populous places. First, namely, with reference to the present state of the case as to excremental refuse, it appears that the ordinary sewage-problem as to the means of preventing nuisance from the outflow of populous places, is not materially lighter in places where water-closets are few or none, and where systems which purport to withhold privy-solids from the sewers are in use, than it is in places where water-closets are general. It appears that in all places of the former class the sewage has in fact under the existing arrangements universally received a very large proportion of human refuse: and that apparently the mere house-slops and street-washings of populous places (not to mention other sources of pollution) must in themselves, under any conceivable system, constitute a highly offensive outflow, requiring substantially the same treatment as the sewage into which water-closets empty. And secondly, the Commission reports that, for populous places which are also seats of manufacture, it would generally be possible, without materially complicating the sewage-problem, to allow the fluid refuse of industrial processes, with few exceptions, to pass into the sewers to be disposed of as common sewage: the special exceptions which are named being the refuse of workers in metal and of manufacturers of gas, paraffin oil, pyroligneous acid and animal charcoal: that, subject to some such exceptions as these and to proper regulations, the discharge of fluid industrial refuse into sewers would generally not render the sewage more difficult of use, and would in some cases, in respect of certain contained refuse-matters, greatly increase the agricultural value of the sewage.

Sewers and drains as means of cleanliness.

30.—Of sewers and drains, with regard to the technic of their construction, I of course do not pretend to speak. All rules applicable to this matter are given in a special Memorandum issued

by the Board for the assistance of local officers, which, as having been prepared by Mr. Rawlinson, the Board's Chief Engineering Inspector, has the authority of an unequalled experience; and my reference to sewers and drains is only in regard of their sanitary results. In proportion as they are skilful or unskilful appliances, so they become powerful influences for good or for evil; and in this point of view, I would urge the necessity of such works (even though on the smallest scale) being always planned with adequate skill and executed under trustworthy supervision. In the same point of view I would also urge the importance of using as channels for liquid refuse none but properly constructed sewers and drains, and ot therefore superseding by such constructions, as soon as practicable, the many now existing mere gutters, or ditches, or rude irregular works of brick or stone, which, originally meant only for rain-water, are incapable of fulfilling in an effective, cleanly and wholesome manner, the purpose for which modern sewers are designed. This recommendation applies not only to cases where the channels receive privy-drainage, but likewise (for reasons previously explained) to cases where they receive only slop-water: and equally in both cases it must be provided that any sewer which is not completely self-scouring shall at due intervals have effective flushing. With regard to the smaller relations of the subject, as represented in the collection of village-slops, useful information will be found in an appended report by Mr. Netten Radcliffe (to which I shall hereafter more particularly refer) on means of preventing excrement-nuisances in towns and villages.

31.—The choice between a water-closet system and a system of so-called dry-privies, is necessarily in each case a question for local judgment on grounds which in great part must be purely local. *Shall water-closets be adopted?*

32.—The advantages of the former where it can be adopted and will be properly worked, are—as regards the supremely important object of getting the refuse continuously and completely removed, too evident to require advocacy. Those advantages however may fail to be realised if the system be adopted without due circumspection; and the conditions which ought to be kept in view in order to avoid any such failure are apparently these three:— *Their advantages where certain conditions can be fulfilled;*

first, that the closets will universally receive an unfailing sufficiency of water properly supplied to them;

secondly, that the comparatively large volume of sewage which the system produces can be in all respects satisfactorily disposed of; and,

thirdly, that on all premises which the system brings into connexion with the common sewers, the construction and keeping of the closets and other drainage-relations will be subject to skilled direction and control.

(*a.*) The water-supply of a place should not be deemed sufficient for a system of water-closets unless it be such that each ordinary water-closet can be flushed as often as it is used. If the supply *as to water-supply;*

be professedly "constant" it must be really constant, subject only to the occasional short interruptions which may be necessary for repairs and the like, and against the possible dangers of which (§ 19) proper precautions must have been adopted; if, on the contrary, it be confessedly intermittent, and therefore require domestic storage of water, the supply of water (sufficient to fill all house-cisterns) should be at least once in every period of 24 hours; and in any case proper mechanical arrangements to prevent waste of water and to secure the water-pipes against entrance of privy-air will be necessary.

as to sewers;

(*b*.) In order to a satisfactory discharge of privy-sewage, properly constructed sewers, with properly located outfall, are of course indispensable: sewers which would also convey the slop-waters, and generally the rain-fall, or more or less of the rain-fall,* of their drainage-area. It may sometimes be the case that sewers already existing and in all respects satisfactorily working as provision for slop-waters and surface-drainage, are of such construction and with such outfall-arrangements as to be suited also for the addition of privy-sewage, or capable at very moderate expense of being rendered so: for as slop-waters partake (in greater or less degree) of the offensive qualities of privy-sewage, sewers which are to convey them require the same sort of care as to construction and outfall-arrangements as if privy-sewage were also to be conveyed. If existing slop-water sewers are offensive or inefficient in the service in which they already act, or if their outfall is such as already to cause nuisance or water-pollution, evidently no such additional service as the conveyance of privy-sewage can be claimed of them in their actual state: but in this class of cases (and according to the degree of offence or inefficiency) the local sewerage would be judged to require reform, even apart from any question of water-closets; and in connexion with any such reform, especially in towns which have or ought to have common waterworks, there will be favorable opportunity for considering whether a system of water-closets should be adopted.

as to communications;

(*c*.) No premises ought, either through water-closets or in any other way, to be brought into drainage-connexion with common sewers unless they can be made reasonably secure against the dangers of sewage-infection. Part of such security would consist in the fact of the sewers themselves being such and in such state as they should be, especially with regard to scouring and ventilation: but a further, very essential, part would depend on the proper situation, construction, and keeping of the drains and drain-inlets of individual premises. In this latter respect, the following conditions ought to be insisted on:—

that every private drain be properly trapped and ventilated in relation to the common sewer, and be itself also properly constructed;

* In some districts special arrangements for the discharge of storm-waters may be necessary; and in some it may be desired to effect as far as practicable a diversion of all clean rainfall from the sewers: but the consideration of questions of this sort will be special to the localities where they arise.

that every private drain having inlets within a house, have ascending from its head or heads into some suitable high position in the open air, and where it cannot infect the interior, a ventilating-pipe or ventilating-pipes of sectional area amply proportionate to its own;

that all slop-water pipes from within houses be provided at their sinks or other inlets with fixed traps, but further, that, as far as practicable, they be separate from privy-pipes, and made to and open over trapped drain-gratings outside the house, not direct into privy-pipes or drains;

that no overflow-pipe from any cistern which furnishes domestic tap-water, nor from any cistern inside a house, be allowed to open directly into any drain or privy-pipe, but be made (as above) to end open in the outer air;

that in cases where water-closets are supplied on a "constant" system, and where generally there will not be storage-cisterns, the entrance of privy-air into water-pipes be prevented by the adaptation of special service-boxes (which also will act as waste-preventers) to all such privies as have not cisterns.

(*d.*) In considering the admissibility of water-closets, it has always to be remembered that the working of an ordinary water-closet is easily deranged, and that water-closets, when out of order, and especially if in the interior of houses, are apt to become very dangerous nuisances. The ordinary water-closet is therefore a thoroughly ineligible form of privy for those who are unlikely to take proper care of it, or are from poverty unable to give it such occasional repairs as it may require. as to users;

(*e.*) Among such classes of population it is of course unfit that any form of in-door privy should ever be sanctioned: but even in the best-ordered houses the occasional danger of in-door water-closets must not be disregarded. Water-closets ought never to stand where they cannot have outside windows: they ought if possible to stand as projections from the body of the house, and with windowed lobbies dividing them from it. as to location.

33.—It must be assumed that, even in large towns, Authorities, exercising their discretion on skilled advice given to them, will sometimes pronounce against the local adoption of a system of water-closets; and even if it be assumed that the number of such cases will eventually be small, yet, at least for the present, great importance attaches to the question of other means by which privy-nuisances in large towns can be prevented. And it is the more necessary that all such means should be well understood and as far as possible perfected, because permanently it must at any rate be the lot of many small towns and of most villages to depend on them rather than on water-closets. Where water-closets not to be adopted, what are the best alternatives for cleanliness?

In a former section of these observations I described at some length the extremely filthy and dangerous arrangements which frequently, or I fear I should say generally, exist in places where water-closets are not in use. Modern experience, however, has shown, and the fact is of the highest sanitary importance, that

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such arrangements are not the necessary alternative to a system of water-closets; but that, failing a water-system, both large and small populations can obtain under other and amended systems of privy-management a complete or comparatively complete freedom from excremental nuisance and injury.

Former and present departmental inquiries.

Evidence to that effect was given five years ago in two most valuable papers which I had the honor of submitting to my Lords of the Council as appendices to my 12th Annual Report: one by Dr. Buchanan on the earth-closet system, the other conjointly by him and Mr. Netten Radcliffe on the privy-systems of various northern towns; and from that time till the present the information collected in these two reports has been the basis of all advice which I have given in the matter to which they relate. Recently, under the Local Government Board, the present state of experience in the same important branch of nuisance-prevention has been made matter of new and large investigation by Mr. Netten Radcliffe; and I have the honor of submitting to you (App. No. 7) his comprehensive and thoroughly practical report on the subject.

Mr. Netten Radcliffe's present report.

34.—The improved systems which Mr. Netten Radcliffe describes start universally with abolishing all such filthy catchment-provisions as I have referred to, and then, in order to meet the sanitary requirements, provide more or less as follows:

Pail-Privies: having as their aim that excremental matter, unaltered, shall be removed from the privies at so short intervals as not to have become offensive; and adopting as means to this end the use of moveable receptacles, which systematically at short intervals are to be changed, clean for dirty by the scavenger; and which, for the prevention of nuisance in this process have close-fitting air-tight lids to be applied to the foul pails under removal.

Ash-Privies: wherein the professed purpose of the north-country midden (to deodorise excrement by covering it with dry house-refuse) is, under strict precautionary conditions, accepted; the intention being, that the space beneath the privy-seat (but no further space) should be converted by careful masonry into a non-porous catchment-chamber, planned in slope and otherwise with particular reference to ease and frequency of systematic scavenging, and necessarily of but small size; and into which chamber, and direct upon the excrement, the ashes of the house are to be thrown, either down the hole of the seat, or with the seat hinged and lifting for the purpose, or otherwise.

Earth-Privies: as introduced by the Rev. H. Moule: purporting to effect under strictly defined conditions such applications of earth to excrement as shall render the latter inoffensive, forming with it a manure which not only can without offence be stored where it is produced, but can also, after being stored and dried, be

used in the privy again and again with the same effect as new earth, and with some progressive increase of manurial value.

Charcoal-Privies: intended to utilise, on the general plan of earth-privies, the still higher disinfectant powers of charcoal, and thus to reduce to a minimum the quantity of disinfectant required: and purporting to have the further advantage that the excrements themselves can be made contributory to the supply of the charcoal.

In certain cases, Local Authorities have special responsibilities as to privies, viz.:

35.—With general reference to the duty of filth-prevention in inhabited areas, it is necessary to observe that the actual management of privies tends to become a function of Local Authorities, first, in proportion as dry privies of any kind are in use in their districts, and, secondly, in proportion as the districts contain dense settlements of ignorant and dirty population.

where dry privies are in use;

(a.) The dry systems, if they are to be generally available in any populous district, must always be vigilantly superintended, or in most cases actually managed, by the Local Authority, and must be managed with forethought and competent skill. The Authority must in the first place decide as to the type of construction to which it will require householders to conform in regard of the placing of privies, and in regard of the plan of their privy-fixtures: not allowing privies to be so placed that the use of them will be a nuisance to houses or will make the privy-scavenage needlessly difficult or offensive, and carefully regulating the plan of the privy-fixtures (whether for earth-privy, charcoal-privy, pail-privy, or ash-privy) in the ways best calculated to prevent nuisance and facilitate scavenging. If the earth-system be adopted the Authority must prepare and supply the earth; if the pail-system be adopted, the Authority must supply the pails; and whether earth-system, pail-system, or ash-system, be adopted, the Authority must (except in individual cases) scavenge the privies and dispose of the refuse which is removed. Pail-privies and ash-privies in towns should be scavenged as far as practicable daily, and even where the population is least dense, at intervals not exceeding a week. Whether the Authority in acting as above shall act through its own officers and servants or through contractors will be a matter of local discretion; but, so far as it acts through contractors, it must of course see strictly to the execution of the contract, and in all cases it will have to make such bye-laws as are wanted to give effect to its system.

and where poor populations are thickly aggregated.

(b.) Sometimes even in country districts, but with more and more frequency in proportion as districts are urban and populous, particular poor neighbourhoods require that their privy-accommodation, whatever be its sort, should be specially cared for, and sometimes (which must be under urban powers) actually provided by the Authority.

Construction of privies for large joint use by lowest class

(c.) Though ordinary water-closets (and particularly within doors) are not proper for the use of dirty and ignorant populations, water-closets, specially constructed with regard to such classes of

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population, and managed or constantly superintended by the Local Authority, seem the best of all yet discovered privy-contrivances for the uncivilised quarters of towns: and in this respect the experience of Liverpool deserves attention, as shewing that freedom from privy-nuisances can be attained in even the lowest of urban quarters on condition that a proper system of trough water-closets is managed by an efficient Local Authority.

and the supervision of such privies.

(*d.*) Whenever privies of any kind are used in common by many families, or are for general public use, it is essential that the Local Authority should have them under constant supervision, and that (whether they are or are not of a sort to require scavenging of contents) the cleanliness of the privy itself should be systematically and strictly cared for. In cases where the use of the privy is common to all comers, servants of the Authority must of course keep it clean: and in cases where the use is common only to a defined group of houses or families, a definite understanding should be had as to the performance of the duty, either by the using families in regular rotation, or by their landlord or someone else on their joint behalf; and some appointed officer of the Authority must see strictly to the performance of the duty. Also in either case the privy must be protected against wilful damage, and wilful or negligent fouling: and vigilance should be used (particularly when the privies are first coming into local use) to detect, with a view to future prevention, any such abuses of the convenience.

Cleanliness as regards (so-called) dry refuse;

36.—In cases where the water-closet system is in full work, and where consequently no excrement-removal has to be done by cart, necessity still remains (at least in populous places) for a certain quantity of other scavenging. In order that nuisance shall not arise from the so-called dry refuse of houses, regularity and frequency of removal are first conditions; and in populous places such removal needs, of course, to be done as a systematic act of the Authority.

must advert to the putrescent quality of parts of it;

(*a.*) It has to be assumed that the dust-heap of each household contains almost invariably more or less of decomposing moist organic matter: the refuse or professed refuse (often far too lavishly so professed) of the different comestibles of the house: the peelings and other waste-bits of vegetables, the guts and other waste-bits of fish or birds, and so forth: and the necessity for frequent removal has to be estimated, not by what the mere fire-ash and other dry dust would require, but by the extreme offensiveness of these usual adjuncts. Households, not of the poorer classes, can, with proper management, keep their dust-heaps comparatively free from organic refuse: the larger households, namely, by daily utilisation of their kitchen-waste, and many smaller households by burning theirs on the kitchen fire. But the moderate amount of care which would serve in these ways to prevent nuisance is in a large proportion of the cases absent, and in other cases, immensely numerous, the suggested prevention would be quite impossible: for the domestic power of burning

refuse is limited by the poverty which must spare fuel, and many large towns have masses of poor population to whom such fires as would consume even the scant potato-peelings or spoilt cabbage-leaves of the house are luxuries entirely unknown. Scavenging-arrangements in relation to house-refuse in towns must therefore be framed with special reference to the fact that such refuse soon becomes highly offensive, and that, except where good domestic management exists, any two-days' retention of it makes a nuisance. It has to be remembered too as an actual fact, though representing a state of things which ought as far as possible to be resisted, that so-called dust-heaps in poor neighbourhoods very often contain some, and not rarely a good deal of excremental matter: cast there sometimes in mere dirty indolence, and sometimes because of a shameful want of other privy-accommodation.

(*b.*) House-refuse, awaiting removal, ought especially not to be exposed to wet. Liquids of course ought never to be thrown with it; and the ash-heap or fixed or moveable receptacle, used for ashes, ought always to be protected against rain. A moveable ash-tub, standing under a shed, is perhaps generally the best receptacle for dry-refuse, is particularly suited to the crowded parts of towns, and is the only proper arrangement for cases where the refuse must be carried through the house. If a fixed dust-bin be used, its walls should be smooth and impermeable, and its location and construction such as to give every facility for sweeping out. No receptacle should be of unnecessary size, but merely large enough to contain such accumulations as must occur in the proper intervals of removal.

must not let it accumulate or get wet;

(*c.*) It is not requisite in this place to say anything with regard to the eventual utilization of dry refuse. But it may be convenient here to note, with regard to cases where utilisation is not in view, that accumulations of offensive refuse may sometimes advantageously be burnt: namely, with the addition, if necessary, of lime, ashes, or other drying material, and with an admixture of cinders or small coal: and that this process (which gives an ash useful for deodorisation) may, in proper situations, be conducted either in coking-ovens, or in suitably-disposed open heaps.

may in some cases advantageously burn it.

37.—I perhaps hardly need note that the due scavenage of public ways is among the requisites for such local cleanliness as the public health requires. The filth of ill-kept streets contains, with the inorganic detritus of road and wheels, large quantities of the dung and urine of horses and occasionally other cattle: while in the courts and alleys of poor neighbourhoods, and even in many obscure streets, the case is made worse by an admixture, sometimes not small, of human excrement: and it is therefore essential that street-refuse should share the general obligation of filth to be promptly and properly removed. In quarters which will admit of it (and especially in poor neighbourhoods) the use of the hose in aid of the shovel and broom may be of great service.

Cleanliness as regards public ways;

and the sanitary importance of good pavement.

Public ways cannot be kept clean unless they are of suitable surface (so paved, namely, as not in any avoidable degree to favor the imbibition or other retention of filth) and are provided with proper rain-channels. In poor neighbourhoods this requires special attention: the extension of good pavement into all courts and alleys, whether legally public or private, is essential to their means of cleanliness: and generally with regard to all yards and curtilages, whether of rich or poor, the provision of impervious pavement on ground which adjoins houses is a valuable security in the same direction. The same rule applies to the basement of houses in regard of parts on which slop or other dirt is apt to fall.

Cleanliness as regards offensive sorts of business, and the keeping of animals.

38.—The general sanitary obligation to prevent injurious action from refuse-matters includes of course that sufficient regard shall be had to the conduct of those sorts of business which produce animal or vegetable refuse, or are in any other way apt to give putrescent effluvia or putrescent outflow. Thus, for instance, slaughtering-places, whether in towns or in villages, always require particular attention, as to their means of water-supply and drainage and ventilation, as to their having proper receptacles and regular prompt removal for all their refuse-products, as to their not occasioning any filthy soakage within or without their limits, and generally as to their being kept in a clean state and (as far as can be) without offensive odor. So of course, in populous places, all keeping of animals requires to be looked after with reference to the due removal of the refuse, and with reference also to animals not being kept (as great numbers of pigs often are) in situations so contiguous to houses that their keeping must necessarily be a nuisance: and, whether in towns or villages, no offensive outflow or soakage should be allowed from any cattle-shed or pig-sty which would not be allowed from a human privy. The action of Local Authorities, or of contractors under them, in collecting and disposing of the solid house-refuse and surface-filth of districts, requires, of course, the same sort of care as other sorts of business which deal with putrescent matter; as particularly as regards places of temporary deposit for collected refuse, and processes which the refuse may there have to undergo, the sites should be so chosen, and the processes so conducted, as not to cause avoidable nuisance.

Abatement of refuse-nuisances when found existing.

39.—In a different point of view to that of the preceding observations, I have yet to mention one more function which has to be discharged by those who would reduce the prevalence of Filth-diseases in England. In an earlier page I noted that, in proportion as a district should be well cared for in such respects as have now been explained, nuisances would so largely be prevented in it that comparatively few could present themselves for removal. Exceptionally however even under such circumstances, and abundantly of course in districts which have been ill-cared for, the abatement of various refuse-nuisances, and particularly the removal

of accumulated refuse, is a duty which has to be performed in order (so far as may still be possible) to the prevention of disease; and I have therefore here to advert to it in that sense.

With reference to houses which are said to have offensive smells, or which Inspectors find in a stinking state, it cannot be too distinctly understood that cleanliness and ventilation and dryness are the proper deodorisers of houses, and that artificial deodorisers will no more serve in their stead than, in regard of persons, perfumes could serve instead of soap and water. As against old frowsy and mouldy states, something supplementary may be got by free washings with hot lime-wash, or, in close spaces, by fumigation with sulphurous acid: but truly to deodorise a house is, to see that no house-refuse (not only no excremental matter, but also no other kind of dirt or refuse, nor any foul old wall-papers or other hangings) remain in or about it; and to see that all proper washings and limewashings be duly done; and to see that its basement be thoroughly dry; and to see that the air within it be not in any part stagnant, but always in course of renewal from without. Similarly, where the complaint is of drainage-odor within a house, search should be made whether the filth which house-drains are meant to carry away is retained in or near the premises in ill-made drains or in cesspools, or perhaps is leaking from house-drains within the house; or whether, inside the house, the inlets of drains and sinks are not properly trapped, or the pipes themselves have holes in them; or whether, outside the house, the ventilation of the drains and sewers is insufficient.

Where offensive matters have been allowed to accumulate in large quantities, the disturbance of them for removal (as in the emptying of ill-conditioned privies or cesspools) ought to be with special precautions; both in order to reduce the mere offensiveness of the process, and also to obviate, as far as may be, the dangers which the effluvia may represent. For the latter purpose, chemicals of an antiseptic sort are perhaps those which will be most generally applicable, and may be such, or in such combination, as also much to deodorise the filth; but, for the limitation of stink, privy-refuse should, at least in populous places, always be removed with special apparatus. Various refuse-heaps and mud-heaps, which for a time it may be impracticable or inexpedient to remove, should be covered, to the depth of two or three inches, with a layer of freshly-burnt vegetable charcoal in powder, or with a layer of clean dry earth, or with a layer of freshly-burnt lime; and earth near dwellings, if it has become foul by the soakage of decaying or vegetable matter, should be treated on the same plan.

40.—Finally, it will be evident that, as the use of impure water is a chief way by which filth-infections get entry to the human body, so, for the prevention of filth-diseases, a very strict insistence on purity of water-supply is quite essential. And this in my opinion is a matter with regard to which no sort of compromise should be considered safe. When proper local arrangements shall

Cleanliness as regards water-supply;

have been made for dealing with the excremental and other organic refuse-matter of inhabited places, many water-supplies which now are a daily danger to life will through that reform become comparatively safe: streams namely at once, and wells after sufficient lapse of time; but I venture to repeat that in this matter a very strict standard of cleanliness is in my opinion essential to safety.

from streams;

As regards running waters, the reports of the Rivers Pollution Commission seem to have clearly shewn that the fouling of natural watercourses by direct infusion of liquid refuse is a nuisance which, at least in all ordinary cases, Local Authorities may reasonably be required to suppress by application of the sewage to land; and though conditions are not yet defined under which streams, otherwise safe as drinking-water, can, without detriment to their potability, receive the outflow from sewage-receiving land, it may, I think, fairly be expected that to fulfil satisfactory conditions in that respect will in general be of no insuperable difficulty. Whether in particular cases populations may be so circumstanced that they cannot refrain from polluting streams, is a question which would in each separate case have to be judged on its own merits: only, if they must pollute the water, let the water be frankly recognised as unclean. Thus, regarding rivers as sources of drinking-water, one of two positions ought, I submit, to be consistently aimed at: either that, being a necessary source of domestic water-supply, the river shall be absolutely protected against pollution; or else that, being (in whatever degree) used as a sewer, it shall be classed as not fit to supply drinking-water.

from wells.

As regards wells, two cases must be distinguished. In the case of densely inhabited areas, it is certain that, however rightly the refuse-disposal may be conducted, the surface-wells can never be other than most dangerous sources of supply; and deep wells (which of course can only be trusted on condition that they are demonstrably protected against the chances of downward pollution) are only possible under certain geological conditions. It must therefore often be, that considerable centres of population will not be safely supplied with water unless the water come from outside the inhabited area; and in regard of the origin and course of any such extrinsic supply, the town population ought to be extremely vigilant. Among comparatively scattered populations, wells (and in great part surface-wells) must often be the source of supply: and it is of the greatest importance to discriminate between such as may and such as may not be safely used, and to ensure for all those which are to continue in use the completest attainable protection against dirt. Wells, adjacent to such privies and other filth-deposits as are now common in rural districts, are probably at present the chief means by which enteric fever spreads in such neighbourhoods; and however much the system of refuse-disposal in such districts may be improved, it can scarcely be hoped that surface-wells contiguous to dwellings (such as particularly the shallow dip-wells attached to cottages) will ever be safe against pollution. It is therefore greatly to be desired

that, in each village, there should as far as practicable be common centres of supply; if possible, springs or deep wells; and, in any case, with the most careful protection against foulings by slovenliness or by accident. In rural districts which (for geological or other reasons) cannot have safe water-supplies by springs or wells as above, arrangements for the collection and storage of rain-water, with every possible care that the water shall be collected and stored without pollution, are necessary to meet the wants of the population; and the receptacles which must be part of any such system ought, if practicable, to be above ground.

41.—Throughout the above observations I have always, I hope, sufficiently shewn that, while regarding Filth as the deadliest of our present removable causes of disease, I am far from regarding it as the only evil influence against which Sanitary Authorities have to contend; and though the object of my present Supplementary Report has been only to advert to the means by which enteric fever and the diseases ætiologically akin to it may be prevented, I would in conclusion observe, that, however admirable may be local arrangements of sewerage and scavenage and water-supply, and however complete in consequence may be the extinction of the diseases which arise exclusively from Filth, other excesses of disease will still have to be extinguished by such other preventive measures as are appropriate to their modes of production. On that subject I do not here pretend to enter: but having above (§ 5) specially named one influence as being, like Filth, of most destructive and probably universal operation throughout England, I would here specially, though but in a word, revert to it. And as regards that deplorable facility with which dangerous contagions of disease are allowed so generally to diffuse themselves in this country, often no doubt by co-operation of Filth, but also often independently of it, I would finally urge, as of interest to all districts, that, side by side with such endeavours for strict cleanliness as it has been the object of my preceding observations to recommend, the utmost vigilance should likewise everywhere be used with regard to all first cases of infectious disease, and everything be done, which the state of the law permits, to prevent the scattering of seeds of contagion.

Reminder, that the preceding observations have aimed only at one group of removable causes of disease.

JOHN SIMON.

APPENDIX.

App. No 1.

Illustrations from Inspectors' Reports.

No. 1.

Illustrations, from Inspectors' Reports of the four years 1870–3, of the circumstances in which Enteric Fever is commonly found prevalent.

Places.	Date of Inquiry.	Ground of Inquiry.	Authorities concerned.	Inspector, and the chief facts reported by him.
Abingdon - - - (Berks.)	1872	Regis.-General's Return.	Abingdon town council. Do. Improvement Commissioners.	*Dr. Thorne.* Enteric fever and diarrhœa. Water supply mostly from surface wells in porous soil soaked with excremental and other filth. Defective sewerage. Subsoil in part waterlogged. Many nuisances from waterclosets and privies. No proper removal of excrement. Poor housed in buildings unfit for habitation.
Annesley - - - (Notts.)	1870	Regis.-General's Return.	Annesley vestry - -	*Dr. Buchanan.* Enteric fever. Arrangements for excrement disposal and water supply such that people must drink their own excrement.
Appledore & Northam (Devon.)	1870	Regis.-General's Return.	Northam local board -	*Dr. Thorne.* Epidemics of enteric fever and scarlatina; chiefly in Appledore, where streets and courts extremely ill-constructed and ill-drained, with excrement and refuse lying about everywhere. Water sources befouled. At Northam polluted water and excrement nuisances.
Armley - - - (Yorks.)	1872	Local information.	Leeds corporation -	*Dr. Ballard.* Enteric fever first attacked dairyman, and then spread to a large number of his customers. His well was found to be extensively contaminated with sewage. (See special report appended, No. 4.)
Ashton in Makerfield (Lancaster.)	1872	Regis.-General's Return.	Ashton local board -	*Mr. Radcliffe.* Epidemic of enteric fever. Water supply insufficient, and partly from questionable sources. Want of outlets for house drains. Accumulations of excrement. Want of scavenging.
Balby-cum-Hexthorpe (Yorkshire.)	1873	Regis.-General's Return.	Doncaster rural sanitary authority.	*Dr. Thorne.* Frequent prevalence of enteric fever. Defective sewerage and drainage. Polluted water supply. Improper means for the disposal of excrement and refuse.
Banbury - - - (Oxon.)	1870	Regis.-General's Return. Several fever deaths in a town where fever had previously been much reduced by sanitary action.	Banbury local board -	*Dr. Buchanan.* Some of the fever found to have been imported; room for further sanitary improvement. In regard of nuisance removal, many conditions worse than on 1866 inspection.
Barking - - - (Essex.)	1873	Regis.-General's Return.	Romford rural sanitary authority.	*Dr. Harries.* Enteric fever prevalent. Unwholesome water. System of drainage and sewerage imperfect. Passage of sewer air into houses. No arrangement for removal of excrement and refuse. Soil saturated with filth. Overcrowding and other nuisances.

Places.	Date of Inquiry.	Ground of Inquiry.	Authorities concerned.	Inspector, and the chief facts reported by him.
Barking - - - (Lodge Farm.)	1873	Question of relation of cases of enteric fever to the sewage irrigation.	—	*Dr. Buchanan.* Enteric fever had occurred among persons living in Barking and working on the sewage farm. No sufficient evidence whether the cause of the fever was on the farm, or in the town. Water of a well on the farm derived largely from sewage effluence. Particular excremental nuisances also in the neighbourhood of this well.
Barlborough - - (Derbyshire.)	1869	Petition from inhabitants.	Barlborough vestry -	*Dr. Thorne.* Prevalence of enteric fever. Nuisances from drains, privies, and waterclosets, and impure water supply in certain parts of the parish.
Barnet - - - (Herts.)	1871	Local complaint.	East Barnet vestry. Barnet guardians.	*Mr. Radcliffe.* Prevalence of fever. Nuisances from cesspools and foul ditches. Water good, but service reservoir open and dirty. Proper system of sewerage required.
Barrow-in-Furness - (Lanc.)	1872.	Regis.-General's Return.	Barrow corporation -	*Mr. Radcliffe.* Prevalence of enteric fever. A rapidly extending town with the population growing faster than house accommodation. Consequent overcrowding. Sewerage imperfect. A considerable portion of town has privies with middensteads, giving rise to much nuisance.
Basingstoke - - (Hants.)	1871	Local complaint.	Town council - -	*Dr. Ballard.* Enteric fever. Polluted wells. Air and soil befouled with excrement from cesspits. No proper drainage. General neglect of sanitary measures.
Bedford - - -	1870	Regis.-General's Return.	Bedford guardians, local board, Wootton vestry - -	*Dr. Thorne.* Endemic enteric fever. Foul and scanty water, with excrement nuisances.
Bideford - - - (Devon.)	1870	Regis.-General's Return.	Bideford local board	*Dr. Thorne.* Prevalence of fever and scarlet fever. Pollution of earth, air, and water by excremental soakage. Badly constructed and unventilated cottages. Abundant other nuisances.
Biggleswade - - (Beds.)	1871	Regis.-General's Return.	Biggleswade vestry and guardians, Potton vestry.	*Dr. Corfield.* Prevalence of scarlatina, measles, and enteric fever. General pollution of earth, air, and water by excrement. Want of privy accommodation. Spread of disease from overcrowded plaiting schools.
Bingham - (Notts.)	1872	Regis.-General's Return.	Bingham guardians. Bingham vestry.	*Dr. Thorne.* Imperfect drainage. Surface soil saturated with excremental filth. Water polluted.
Bishops Stortford (Herts.)	1873	Regis.-General's Return.	Local board - -	*Dr. Thorne.* Frequent prevalence of enteric fever. Polluted water supply. Sewers imperfectly ventilated, and consequent nuisance from the escape of sewer air into dwellings. Imperfect means for disposal of excrement and refuse. Privies and waterclosets badly constructed, the latter not properly supplied with water.
Blyth - - - (Northumberland.)	1872	Regis.-General's Return.	Blyth local board. Cowpen local board. Tynemouth guardians.	*Dr. Airy.* Enteric fever endemic in Cowpen township, where the water supply is insufficient and bad. Sewers not properly ventilated. System of excrement removal defective.

Places.	Date of Inquiry.	Ground of Inquiry.	Authorities concerned.	Inspector, and the chief facts reported by him.
Bolton Registration District.	1871	Regis.-General's Return.	Bolton Local board. Bolton guardians and various vestries. Farnworth local board. Kearsley do. Halliwell do. Astley Bridge do.	*Dr. Ballard.* High mortality especially of children, and great prevalence of diarrhœa. *Bolton town.* Houses of operatives crowded together, badly ventilated, and often unfit for human habitation. Badly constructed privies and ashpits, and neglect of them by the local authority. Imperfect scavenging and cleansing of the town, insufficient arrangements for sanitary inspection, and almost complete neglect of the provisions of the Sanitary Act, of 1866, relating to the arrest of the spread infectious diseases. *Farnworth, Kearsley, Halliwell, and Astley Bridge (in varying degrees).* Houses badly ventilated and premises undrained; overcrowding; privies and ashpits badly constructed and neglected; nuisances not removed; insufficient arrangements for sanitary inspection, and neglect of the provisions of the Sanitary Act, 1866, relating to the arrest of the spread of infectious diseases. *Other parts of the Bolton Union.* Houses badly ventilated or unfit for human habitation; premises undrained; overcrowding; insufficient privy accommodation; privies and ashpits badly constructed and neglected; nuisances not removed; in some places insufficient and bad supply of water; insufficient arrangements for sanitary inspection, and general neglect of the provisions of the Sanitary Act, 1866, relating to the arrest of the spread of infectious diseases.
Brackley - - - (Northamptonshire.)	1871	Regis.-General's Return.	Brackley guardians, and joint Sewerage Committee. Newbottle vestry.	*Dr. Buchanan.* Epidemic of enteric fever. Accumulation of excrement. Wells near cesspools.
Bradford - - - (Yorks.)	1871	Regis.-General's Return.	Local board - -	*Mr. Radcliffe.* Prevalence of fever and diarrhœa. Much nuisance from privies with middensteads, imperfect drainage of courts, and open watercourses. Defective sanitary administration.
- - -	1872	Regis.-General's Return.	Bradford corporation	*Mr. Radcliffe.* Sanitary defects pointed out in last year's report not removed. Much nuisance.
Brecknock - - -	1873	Regis.-General's Return.	Town council - -	*Dr. Harries.* Enteric fever. Defective drainage. Imperfect system of excrement disposal. Cesspits leaky and rarely emptied, and consequent pollution of soil water. Badly constructed and improperly placed privies. Some houses unfit for habitation. Nuisances from animals and from accumulations of manure.
Bridport - - - (Dorset.)	1870	Continued prevalence of fever, and unsatisfactory answer from board respecting action taken on former advice of Department.	Bridport local board -	*Dr. Buchanan.* Increased prevalence of epidemic disease; continuance of unwholesome conditions previously reported; general foulness of water; accumulations of excrement; general neglect of sanitary functions by board.
Bruton - - - (Somerset.)	1872	Regis.-General's Return.	Wincanton guardians. Bruton vestry.	*Dr. Home.* Enteric fever. Excremental and other nuisances close to dwellings. Soil and water polluted with sewage.

Places.	Date of Inquiry.	Ground of Inquiry.	Authorities concerned.	Inspector and the chief facts reported by him.
Bulwell - - - (Notts.)	1871	Report of district medical officer.	Bulwell vestry. Basford guardians.	*Dr. Harries.* Epidemic of enteri fever. Pollution of water by excrement nuisances. Privies filthy an insufficient.
Burbage - - - (Leicestershire.)	1871	Report from local registrar.	Aston Flamville vestry. Hinckley guardians.	*Dr. Harries.* Epidemic of enteric fever connected with use of water from a well communicating with a privy probably infected by an imported case of enteric fever. Bad excrement management, and improper water supply generally.
Burton Latimer - - (Northampton.)	1872	Local information.	Kettering rural sanitary authority.	*Dr. Thorne.* Epidemic of enteric fever. Water suppply obtained from wells polluted by soakage from privies and cesspools. Sewerage and drainage defective. Accumulations of excrement and refuse. Nuisance from piggeries. Overcrowding.
Calstock - - (Cornwall.)	1871	Local information.	Calstock vestry. Tavistock guardians.	*Dr. Blaxall.* Frequency of epidemics; constant prevalence of enteric fever and diarrhœa. Continuance of unwholesome conditions previously reported. General absence of proper drainage. Want of privy accommodation. Excrement nuisances. Polluted water.
Campden - - - (Gloucestershire.)	1873	Local information.	Shipston-on-Stour rural sanitary authority.	*Dr. Harries.* Enteric fever has been more or less prevalent for the last three years. Polluted wells. Nuisances from house drainage and from defective system of excrement and refuse disposal.
Cardigan - - -	1870	Regis.-General's Return.	Town council - -	*Mr. Radcliffe.* Insufficient privy accommodation; imperfect sewerage; nuisances from collections of manure, from ashpits, and from pigsties; foul brook through the town.
Carlton - - - (Notts.)	1871	Local complaint.	Carlton vestry. Basford guardians.	*Dr. Harries.* Enteric fever epidemic. No proper water supply. Privies few and bad. Nuisances abounding.
Castle Cary - - (Somerset.)	1872	Regis.-General's Return.	Wincanton guardians. Castle Cary vestry.	*Dr. Home.* Frequent prevalence of enteric fever. Old-standing faults of drainage and water supply, but works of sanitary improvement in progress.
Castleford - - - (Yorks.)	1870	Regis.-General's Return.	Local board - -	*Mr. Radcliffe.* Prevalence of fever. Excremental nuisances. Sewerage defective. New water supply in course of provision.
Chatham (*See* Rochester.)				
Chippenham - - (Wilts.)	1870	Regis.-General's Return.	Chippenham local board.	*Dr. Buchanan.* Prevalence of enteric fever and other epidemics. Insufficient and impure water supply; want of privy accommodation and of a proper system of excrement disposal; faulty house construction.
Chipping Sodbury Union (Gloucester).	1872	Report of Vaccination Inspector.	Chipping Sodbury rural sanitary authority.	*Dr. Ballard.* Prévalence of enteric fever and diarrhœal affections. Absence of sanitary supervision. Want of drainage and pure water supply in various parts of union, especially in Marshfield. Unhealthy state of cottages.
Chittlehampton - - (Devon)	1872	Regis.-General's Return.	Chittlehampton vestry South Molton guardians.	*Dr. Home.* Prevalence of enteric fever. Drainage imperfect. Privies ill-constructed, some cottages without privies. Accumulations of excrement. Polluted water. Nuisances.

Places.	Date of Inquiry.	Ground of Inquiry.	Authorities concerned.	Inspector, and the chief facts reported by him.
Clifton Reynes - - (Bucks)	1872	Local information.	Newport Pagnell guardians. Clifton Reynes Vestry.	*Dr. Thorne.* Enteric fever. Water supply partly polluted. Some nuisances.
Combrooke - - - (Warwick.)	1873	Report from Vaccination Inspector.	Stratford-on-Avon rural sanitary authority.	*Dr. Ballard.* Enteric fever had been imported from Leamington, and spread in the house to which the patient was brought, and to the two adjoining houses. Water used in these houses was obtained from a well exposed to pollution. Imperfectly constructed privies in the village generally.
Coventry (neighbourhood of). (Red Lane Estate.)	1870	Communication from local registrar.	Coventry guardians. Foleshill guardians. Coventry local board. Foleshill vestry.	*Dr. Thorne.* Enteric fever found seriously prevalent, and ascribed to use of polluted water, want of efficient sewerage, and various filth accumulations.
Croyde - - - (Devon)	1870	Regis.-General's Return.	Barnstaple guardians. Georgeham vestry.	*Dr. Home.* Serious prevalence of enteric fever. No public sewerage or house drainage. Accumulations of excrement and refuse. Nuisance from pigsties and dungheaps. Water sometimes used from polluted source.
Cwmbran and Pontnewydd (Mon.) -	1870	Regis.-General's Return.	Pontypool guardians. Llanvrechfa and Llantarnam vestries.	*Mr. Radcliffe.* Prevalence of enteric fever. Defective and sometimes impure water supply, and insufficient means of excrement removal.
Doncaster - - - (Yorks.)	1873	Regis.-General's Return.	Town council.	*Dr. Thorne.* Large general and infantile mortality; endemic enteric fever and diarrhœa; epidemic scarlet fever and smallpox. Polluted water. Bad means of excrement disposal. Escape of sewer air into dwellings. Nuisances from piggeries. Neglected courts.
Draycott - - - (Derby.)	1872	Regis.-General's Return.	Shardlow guardians.	*Dr. Beard.* Enteric fever. Defective drainage. Accumulation of excrement. Want of proper sanitary supervision.
Dudley - - - (Worc.)	1871	Regis.-General's Return.	Town council and local board.	*Dr. Thorne.* Endemic scarlatina, typhus, enteric fever, and diarrhœa. Defective and insufficient sewerage. Polluted water in private wells. Inefficient excrement and refuse disposal. Ill-constructed, filthy, and overcrowded houses. Nuisances from pigsties.
Eastbourne - - - (Sussex.)	1870	Local complaint.	Eastbourne local board	*Dr. Thorne.* Prevalence of enteric fever. In the new town sewers not properly ventilated, waterclosets not supplied with water. In the old town drinking water polluted.
Eastwood. (*See* Greasley.)				
Ecton - - - - (Northampton.)	1872	Report of district medical officer.	Wellingborough rural sanitary authority.	*Dr. Buchanan.* Fever caused by the use, for drinking, of water from a brook polluted by sewage. Subsequent spread through excremental nuisances. Wells polluted by soakage from privies and pigstyes. Overcrowded cottages.
Emberton - - - (Bucks.)	1872	Local information.	Newport Pagnell guardians. Emberton Vestry.	*Dr. Thorne.* Enteric fever. Dilapidated cottages. Water polluted by sewage. Want of system for disposal of excrement.
Forest Hill - - - (Kent.)	1870	Local complain	Lewisham board of works. Camberwell vestry.	*Mr. Radcliffe.* Prevalence of zymotic diseases. Disease produced by deficient and imperfect sewerage, and by foul cesspools.

Places.	Date of Inquiry.	Ground of Inquiry.	Authorities concerned.	Inspector, and the chief facts reported by him.
Frogmore and Two Waters - - - (Herts.)	1870	Local complaint.	Hemel Hempstead guardians. Hemel Hempstead vestry.	*Dr. Thorne.* Enteric fever found to be endemic. Drains choked and ground saturated with filth; privies and ashpits foul, and polluted drinking water.
Glastonbury - - (Somerset.)	1870	Local complaint.	Wells guardians. Glastonbury town council.	*Mr. Radcliffe.* Excessive mortality from scarlatina and enteric fever. Water supply insufficient; sewers defective; arrangements for excrement disposal utterly bad.
Goole - - - - (Yorks.)	1871	Report of Vaccination Inspector.	Goole vestry and guardians. Hook vestry.	*Dr. Home.* Epidemic diarrhœa, some choleraic. Occasional prevalence of enteric fever. "Every kind of in-" sanitary condition in the most " aggravated form." Bad water; excrement accumulation; imperfect sewerage; houses huddled together without plan. Interiors overcrowded and fœtid.
Greasley and Eastwood (Notts.)	1870	Regis.-General's Return.	Basford guardians. Eastwood vestry. Greasley vestry.	*Dr. Buchanan.* In both parishes enteric fever had prevailed, along with general pollution of air and water by excrement; insufficient water supply, and various nuisances. The vestries had practically decided not to perform their duties under the Sanitary Acts.
Great Grimsby - - (Linc.)	1871	Regis.-General's Return.	Local board - -	*Dr. Home.* Prevalence of diarrhœa and fever; polluted water; inefficient system of excrement and refuse removal; incomplete drainage and sewerage. Nuisances. Houses unfit for habitation. Inadequate sanitary supervision.
Guisborough - - (Yorks.)	1873	Regis.-General's Return.	Guisborough local board.	*Dr. Harries.* Serious prevalence of enteric fever. Polluted water. Nuisance from privies and refuse. Imperfect arrangements for scavenging. Ill-built and overcrowded houses.
Hawkesbury Upton - (Glouc.)	1873	Report of Vaccination Inspector.	Chipping Sodbury rural sanitary authority.	*Dr. Ballard.* Enteric fever. No public drainage. Open cesspools. Sewage habitually soaking into wells.
Heanor - - - - (Derby.)	1870	Regis.-General's Return.	Heanor local board. -	*Dr. Buchanan.* Enteric fever. Offensive privies; water supply very precarious, and in some cases of doubtful purity.
Helions Bumpstead - (Essex and Cambs.)	1871	Local complaint.	Risbridge guardians Helions Bumpstead vestry	*Dr. Airy.* Epidemic enteric fever. Great accumulations of excrement and filth. Foul ditches. Much of the water supply impure.
Helston - - - (Cornwall.)	1870	Local complaint	Helston corporation.	*Dr. Buchanan.* Enteric fever had been prevalent. Water supply scarce and of doubtful quality; little or no drainage; want of privy accommodation; bad arrangements for excrement removal; the town generally filthy.
Hennock - - - (Devon.)	1870	Local complaint.	Hennock vestry - -	*Dr. Hunter.* Enteric fever in Hennock hamlet and in Chudleigh Knighton hamlet; 47 cases of diphtheria, 10 fatal, in six months. Want of privy accommodation and ashpits. Water supply of doubtful purity, and not duly accessible.
Hersham - - - (Surrey.)	1872	Local information - -	Walton - on - Thames vestry.	*Dr. Thorne.* Prevalence of fever, scarlet and enteric. No drainage. Water used from wells polluted by soakage from privies and cesspools. Excremental and other nuisances.

Places.	Date of Inquiry.	Ground of Inquiry.	Authorities concerned.	Inspector, and the chief facts reported by him.
Higham Ferrers (Northampton.)	1871	Local complaint.	Higham Ferrers vestry, Wellingborough guardians.	*Dr. Home.* Habitual prevalence of enteric fever, not only in sewered houses. Ground sodden with leakage from privy pits and cesspools. Water polluted. Insufficient ventilation of sewers. Accumulations of excrement and house filth. Trade nuisances.
Hucknall-under-Huthwaite. (Notts.)	1873	Regis.-General's Return.	Local board	*Dr. Harries.* Prevalence of enteric fever. Water supply insufficient and liable to pollution from surface drainage. Imperfect system of sewerage and of excrement disposal. Roads badly constructed and in a foul condition. Nuisances.
Hucknall Torkard (Notts.)	1872	Report from local Registrar.	Local board	*Dr. Harries.* Enteric fever endemic. Water supply plentiful, but obtained chiefly from wells which are in a porous soil, and liable to pollution from privies and surface drainage. Insufficient privy accommodation. No systematic provision for excrement disposal. Foul accumulations of all kinds. Serious overcrowding of houses in which colliers lodge.
Hugglescote, Donnington, Coalville, and Packington. (Leic.)	1871	Regis.-General's Return.	Vestry of Hugglescote and Donnington, Ashby-de-la-Zouch guardians.	*Dr. Home.* Enteric fever severely epidemic. Air and water polluted by excrement. No proper drainage. Nuisances from privies and pigsties.
Huddersfield (Yorks.)	1872	Regis.-General's Return.	Huddersfield corporation	*Dr. Buchanan.* Epidemic of enteric fever. Sewers defective. Arrangements for excrement disposal inadequate. Certain water supplies largely polluted with sewage. Necessity for appointment of medical officer of health, and for construction of a hospital for infectious diseases, and a mortuary. Corporation have improvements in progress.
Ilkeston (Derby.)	1870	Local complaint.	Ilkeston local board	*Dr. Buchanan.* Enteric fever found to be endemic. Imperfect drainage; air and drinking water polluted by excrement; filthy ashpits.
Ilminster (Som.)	1871	Report from Guardians.	Ilminster sewage board. Chard guardians.	*Dr. Blaxall.* Considerable epidemic of enteric fever. Foul open sewers. Excremental filth everywhere, saturating ground and contaminating most of drinking water.
Ingham (Lincoln.)	1870	Local information.	Ingham vestry	*Mr. Radcliffe.* Fever, chiefly enteric, had been prevalent, and had been caused by polluted water; excremental pollution of earth about houses from defective house drains and bad privies. Overcrowding.
Kilgerran (Pembroke.)	1870	Regis.-General's Return.	Kilgerran vestry	*Mr. Radcliffe.* Very scanty water supply: liable to become polluted. No proper provision for excrement or refuse disposal. Imperfect sewerage.
Kingsthorpe (Northampton.)	1870	Regis.-General's Return.	Kingsthorpe vestry	*Dr. Buchanan.* Prevalence of scarlatina, enteric fever, and diarrhœa. Want of drainage. Water polluted. Accumulations of excrement and filth. No means of isolation or disinfection.
Leeds (Yorks.)	1871	Regis.-General's Return.	Corporation	*Mr. Radcliffe.* Excessive mortality from diarrhœa and fever. Most offensive form of excrement disposal by common privies. Faulty regulation of sewers. Inadequate water supply. Ill-constructed buildings. Want of scavenging.

Places.	Date of Inquiry.	Ground of Inquiry.	Authorities concerned.	Inspector, and the chief facts reported by him.
Leigh - - - (Lanc.)	1872	Regis.-General's Return.	Local board, Atherton. Ditto West Leigh. Ditto Pennington. Ditto Bedford.	*Mr. Power.* Epidemic of enteric fever. Privy accommodation insufficient. Polluted water used from wells close to drains, privies, and middens. Accumulations of excrement. Imperfect sewers. Badly constructed and arranged houses.
Littleport - - - (Cambs.)	1873	Regis.-General's Return.	Ely rural sanitary authority.	*Dr. Thorne.* Enteric fever endemic. Water supply generally insufficient and in part polluted. Nuisances from imperfect drainage, from cesspools and privies. No proper provision for removal of excrement and refuse. Some cottages dilapidated and otherwise unfit for habitation.
Llanelly - - - (Brecon.)	1872	Regis.-General's Return.	Brynmawr local board. Crickhowell guardians.	*Dr. Harries.* Prevalence of enteric fever. Water polluted by sewage. Nuisances. Many houses without privies. No system of excrement removal or of scavenging.
Llanelly - - - (Carmarthen.)	1870	Regis.-General's Return.	Llanelly local board -	*Mr. Radcliffe.* Prevalence of enteric fever. Provisions for excrement disposal and refuse removal fundamentally defective. Drainage defective, and water supply inadequate for the wants of the sewer system.
Lye, The - - - (Worc.)	1873	Regis.-General's Return.	Stourbridge rural sanitary authority.	*Dr. Ballard.* Enteric fever. No proper drainage. Insufficient supply of water. Polluted wells. Nuisances from accumulations of manure and from privies and ashpits.
Macclesfield - - (Certain portions of the Union.)	1873	Information from General Inspector and from rural sanitary authority.	Macclesfield rural sanitary authority. Bollington local board.	*Dr. Thorne.* Epidemic of scarlet fever, and frequent prevalence of enteric fever and diarrhœa. No means either of isolation or of disinfection. Bad cottage property. Polluted water. Insufficient and imperfect drainage. Bad arrangements for disposal of excrement and refuse.
Malpas - - - (Chesh.)	1871	Regis.-General's Return. Complaint of rector.	Malpas vestry - -	*Dr. Stevens.* Enteric fever. Drainage defective. Water insufficient and impure. Abundant filth accumulations. Privy accommodation bad. No proper means of refuse disposal. Dwellings unfit for habitation and overcrowded.
Margate - - - (Kent.)	1873	Local complaint.	Town Council - -	*Dr. Harries.* Constant prevalence of fever, diarrhœa, and other low types of disease. Main sewer so constructed as to form a reservoir for sewage, which the tide occasionally drives back through the gratings. Nuisances from sewage outfalls. Rocks and beach near jetty covered with sewage slime. Cesspits estimated to cover aggregate extent of three acres; many under houses, and discharging foul air into them, the sewage sometimes even welling up through the floors. Various nuisances.
Marylebone - - (Middl.)	1873	Local information.	Marylebone vestry -	*Mr. Radcliffe.* See special report appended, No. 6.
Mendham - - - (Suffolk.)	1873	Representations of Hoxne rural sanitary authority.	Hoxne rural sanitary authority.	*Dr. Airy.* Continued prevalence of enteric fever. Wells polluted by sewage. Insufficient privy accommodation. No systematic removal of excrement.

Places.	Date of Inquiry.	Ground of Inquiry.	Authorities concerned.	Inspector, and the chief facts reported by him.
Mexborough (Yorks.)	1873	Regis.-General's Return.	Mexborough local board.	*Dr. Thorne.* Habitual prevalence of enteric fever. Epidemic of scarlet fever and small pox. Bad and insufficient drainage. Polluted water. Accumulations of excrement and filth. No proper means of disinfection and isolation.
Middlesborough (Yorks.)	1871	Regis.-General's Return. Memorial as to nuisance.	Middlesborough local board. Stockton guardians.	*Dr. Buchanan.* Prevalence of small-pox, scarlatina, diarrhœa, and fevers. Pervious sewers, ill-ventilated. Imperfect arrangements for excrement disposal. Old houses ill-constructed.
Milborne Port (Somerset.)	1872	Regis.-General's Return.	Wincanton guardians. Milborne Port vestry.	*Dr. Home.* Constant prevalence of fever. Nuisances close to dwellings. Water and air polluted with sewage.
Milton and Sittingbourne. (Kent.)	1870	Regis.-General's Return.	Milton guardians. Milton Commissioners. Sittingbourne local board.	*Dr. Buchanan.* Much enteric fever. In Milton town great defects in drainage, in excrement disposal, and in water supply, with need for "almost all sanitary improvements "which it is possible to enumerate." In Sittingbourne inefficient arrangements for excrement removal, and wells polluted.
Moseley and Balsall Heath. (Worc.)	1873	Memorial from inhabitants.	Balsall Heath local board. King's Norton rural sanitary authority.	*Dr. Ballard.* Enteric fever broke out at a dairyman's. Fever evacuations thrown out into the privy. Fever spread among customers of two dairymen whose wells were polluted by soakage from this privy. (See special Report appended, No. 5.)
Northam. (*See* Appledore.)				
Northampton	1871	Regis.-General's Return.	Town council and improvement commissioners.	*Dr. Buchanan.* Prevalence of scarlatina, fevers, and diarrhœa. Saturation of soil in low-lying parts. Cesspool soakage. Foul private wells. Improved means of nuisance removal and excrement disposal required.
Nunney (Somerset.)	1872	Report from local registrar.	Frome rural sanitary authority.	*Dr. Ballard.* Prevalence of enteric fever. Water supply obtained chiefly from a brook largely polluted by sewage. Insufficient privy accommodation. No proper system of excrement disposal.
Oldbury (Worc.)	1870	Regis.-General's Return.	Oldbury local board	*Dr. Thorne.* Prevalence of fever and diarrhœa. The place almost absolutely destitute of drainage; water supply very defective, and largely polluted. Nuisance from pigsties, foul privies, middens, and refuse heaps.
Olney (Bucks.)	1872	Local information.	Newport Pagnell guardians. Olney vestry.	*Dr. Thorne.* Constant prevalence of enteric fever. Imperfect drainage. Soil round wells sodden with soakage from privies. Cottages without privies or ashpits. Want of system for disposal of excrement.
Ovendon (Yorks.)	1873	Regis.-General's Return	Local board	*Dr. Thorne.* Large general and infantile mortality. Prevalence of enteric and scarlet fever. Instances of water pollution. Insufficient means of drainage. Bad means of excrement disposal.

Places.	Date of Inquiry.	Ground of Inquiry.	Authorities concerned.	The Inspector and the chief facts reported by him.
Oxford - - -	1870	Regis.-General's Return.	Oxford local board -	*Dr. Buchanan.* Large mortality from epidemics, especially scarlatina, enteric fever, and diarrhœa. Saturation of soil in low-lying parts. Sewer system incomplete. Pollution of streams by sewage. Questions about public water supply. Other water sources all dangerous. Bad construction of poor houses. Insufficient sanitary supervision. Inadequate measures for preventing contagion.
Packington - - (Leic. and Derby.)	1871	Information from local Registrar.	Vestries of Packington, Ibstock, and Whitwick; local board, Whitwick. Ashby-de-la-Zouch guardians.	*Dr. Home.* Severe epidemic of enteric fever. Water supply polluted. Very serious accumulations of excrement and other filth, and other nuisances.
Penally - - - (Pembroke.)	1870	Regis.-General's Return.	Pembroke guardians. Penally vestry.	*Mr. Radcliffe.* Much enteric fever. Water sources liable to pollution. Privy accommodation bad or absent. No proper means of refuse disposal.
Penryn - - - (Cornwall.)	1870	Local complaint.	Falmouth guardians. Penryn Town Council. St. Gluvia's vestry. Budock vestry.	*Dr. Thorne.* Considerable outbreak of enteric fever. Streets lined with excrement and refuse. Want of sewers, privies, and ashpits. Water sources polluted. Overcrowding.
Porchester - - - (Hants.)	1872	Report from inhabitants.	Fareham rural sanitary authority.	*Dr. Stevens.* Prevalence of small-pox and fever. No system of drainage. Privy accommodation bad and insufficient. Water supply obtained from shallow wells into which sewage soaks. Nuisances from pig sties, &c. Some of the cottages unfit for habitation.
Pontnewydd. (*See* Cwmbran.)				
Radford - - - (Notts.)	1870	Regis-General's Return.	Radford vestry. Radford guardians.	*Dr. Thorne.* Prevalence of fever and diarrhœa. Want of privies. Sewers insufficient and ill-ventilated. Water, air, and soil generally contaminated by excrement.
Do. - - -	1872	- - - - - - -	Do. - - -	*Dr. Thorne.* Further prevalence of enteric fever. Escape of sewer air into houses from unventilated sewers. Water source polluted by soakage from privies. Sanitary measures urged in previous report only in small part carried out. Prevalence of small-pox as well as of enteric fever.
Rainford - - - (Lanc.)	1871	Local information.	Rainford vestry. Prescot guardians.	*Dr. Beard.* Prevalence of enteric fever. Pollution of water from sewage and soakage from dung heaps.
Rochester and Chatham (Kent.)	1870	Regis.-General's Return.	Medway guardians, Rochester Town Council, St. Margaret's Paving Commissioners, Rochester Paving Commissioners, Chatham local board, Gillingham vestry, and various other bodies.	*Dr. Buchanan.* Prevalence of fever. Division of sanitary functions among numerous authorities. Absence of soil drainage in various low-lying parts. Bad arrangements for excrement disposal. Pollution of many private wells. Some overcrowding. Insufficient provision for removal of nuisances. These conditions more in Rochester than in Chatham.
Rolvenden - - - (Kent.)	1870	Local information.	Tenterden guardians. Rolvenden vestry.	*Dr. Thorne,* Enteric fever found epidemic. Water supply polluted. Want of drainage and proper means of excrement disposal. Abundant nuisances.

Places.	Date of Inquiry.	Ground of Inquiry.	Authorities concerned.	Inspector, and the chief facts reported by him.
Ross - - - - (Hereford.)	1870	Regis.-General's Return.	Ross improvement commissioners.	*Dr. Thorne.* Epidemic scarlatina and frequent enteric fever. Want of means for excrement and refuse removal. Water supply polluted. Cattle nuisances.
Rotherham - - - (Yorks.)	1872	Local information.	Corporation - -	*Dr. Ballard.* Enteric fever endemic. Neglected state of courts inhabited by the poor. Sewers defective. Nuisances from overfull privies. Air, soil, and water polluted with sewage.
Ruthin - - - (Denbigh.)	1871	Local complaint.	Local board - -	*Dr. Home.* Apparently typhus as well as enteric fever had prevailed. The latter had chiefly attacked severed houses. Ground saturated with excrement and water supplies impure. Unventilated, dirty crowded houses.
St. Dogmaels - - (Pemb.)	1870	Regis.-General's Return.	St. Dogmael's vestry.	*Mr. Radcliffe.* Prevalence of fever. Insufficient water supply, liable to pollution. Imperfect drainage. Bad privies, and want of privy and refuse arrangements.
St. Just - - - (Cornwall.)	1870	Regis.-General's Return.	Penzance guardians. St. Just vestry.	*Dr. Buchanan.* Scarlatina very fatal. Enteric fever habitually present. No precautions against infection. Almost universal foulness of soil and air about houses. Want of provision for excrement removal. Scanty and impure water supply. Unwholesome houses.
Saltash - - - (Cornwall.)	1871	Local information.	Vestry - - - -	*Dr. Hunter.* Prevalence of fever. Danger of epidemics from bad privies. Water supply inadequate.
Scothern - - - (Lincoln.)	1870	Report from Inspector.	Lincoln guardians. Scothern vestry.	*Mr. Radcliffe.* Enteric fever prevalent for last two years. Ground sodden with filth from imperfect drains. Bad privies and refuse receptacles. Water probably polluted.
Sheerness - - - (Kent.)	1870	Regis.-General's Return.	Sheppey guardians. Sheerness local board.	*Dr. Buchanan.* Prevalence of enteric fever. Universal accumulations of excrement. Imperfect water supply. Deficient supervision over sub-let and lodging houses. Inefficient dealing with nuisances.
Sherborne - - - (Dorset.)	1873	Information from Vaccination Inspector.	Local board - - -	*Dr. Blaxall.* Sudden and severe outbreak of enteric fever, affecting chiefly houses supplied from public waterworks. Water in surface mains exposed to contamination from waterclosets. Many ordinary sanitary defects. (See Special Report appended No. 2.)
Sittingbourne (*see* Milton).				
Skegby and Fulwood - (Notts.)	1873	Regis.-General's Return.	Mansfield rural sanitary authority.	*Dr. Harries.* Enteric fever. New houses at Skegby built without due regard to sanitary considerations. Polluted water. Nuisance from drainage.
Spinkhill - - - (Eckington.) (Worc.)	1870	Local information.	Eckington vestry -	*Dr. Thorne.* Habitual prevalence and present outbreak of enteric fever. Water of public and other wells polluted. Drains defective. Want of privies and ashpits; accumulations of filth.

Places.	Date of Inquiry.	Ground of Inquiry.	Authorities concerned.	Inspector, and the chief facts reported by him.
Stamford (Linc.)	1870	Local complaint.	Stamford town council.	*Mr. Radcliffe.* Fever habitual, caused by sanitary defects. Drink water found polluted. Privies ba constructed; excrement accu lating in enormous cesspools. proper system of sewers.
Stevenage (Herts.)	1873	Regis.-General's Return.	Hitchin rural sanitary authority.	*Dr. Thorne.* Frequent prevalenc enteric fever. Very imperfect con tions of sewerage and drainage. I luted water. Want of proper me for the disposal of excrement refuse. Dilapidated cottage prope
Stowmarket (Suff.)	1871	Regis.-General's Return.	Local board	*Dr. Corfield.* Town generally cle Water probably polluted. Fil condition of new parts and subu of town.
Sunderland (Durham.)	1871	Regis.-General's Return.	Local board	*Mr. Radcliffe* Epidemics of typh enteric fever, and small-pox. Ov crowding. Defective drainage. I properly regulated waterclosets, generally imperfect and insuffici arrangements for preventing exc mental nuisances. Defective wa supply to tenemented houses.
Sutton-in-Ashfield (Notts.)	1873	Regis.-General's Return.	Sutton local board	*Dr. Harries.* Frequent prevalence enteric fever. Wells exposed to p lution by surface drainage. Sew unsuitable and insufficient. I proper system of sewage dispos Insufficient privy accommodati Nuisance from overflowing privie
Sutton Veny (Wilts.)	1872	Memorial from vestry.	Sutton Veny vestry. Warminster guardians.	*Dr. Airy.* Epidemic of scarlatina some enteric fever. Want of lation of sick and of disinfecti Bedrooms ill-ventilated. Nuisan from privies and pigsties.
Swanage (Dorset.)	1872	Report from guardians.	Guardians, Wareham. Vestry, Swanage.	*Dr. Home.* Enteric fever. Nea all the inhabitants drink wa exposed to pollution by sew No system of public sewer except at Durlston Park. Ac mulations of excremental ma and house refuse near dwelli Insufficient privy accommodati Scavenging wanted.
Swinton (Yorks.)	1872	Local information.	Rotherham rural sanitary authority.	*Dr. Ballard.* Enteric fever enden Nuisances. Soakage of excremen filth into wells. No proper arran ments for disposal of excrem and removal of nuisances.
Tamerton Folliott (Devon.)	1871	Representation of Plympton guardians.	Vestry	*Dr. Hunter.* Defective privy syst Pollution of drinking water.
Tenby (Pembroke.)	1870	Regis.-General's Return. High mortality from fever.	Tenby local board.	*Mr. Radcliffe.* Prevalence of teric fever. Water supply ins cient, perhaps locally pollu Sewers unventilated. Bad sys of excrement and refuse remo Ill-kept fish market.
Torpoint (Cornwall.)	1871	Local information.	Anthony vestry	*Dr. Hunter.* Serious prevalen enteric fever. Great want of w Sewage nuisances in consequen

Places.	Date of Inquiry.	Ground of Inquiry.	Authorities concerned.	Inspector, and the chief facts reported by him.
Tottenham - - - (Middlesex.)	1873	Regis-General's Returns.	Local board - -	*Mr. Radcliffe.* Serious outbreak of enteric fever. High rate of mortality from fever and diarrhœa. Absence of proper ventilation of sewers. Water supply contaminated with decaying animal refuse. Ill-designed cesspools in parts not sewered. Nuisance from watercourses and ditches used as sewers, and from large deposit of sewage mud at the sewage works. Flow of sewage from the sewers disturbed by flood in February; consequent effusion of sewage on the lower parts of the village, and the escape of sewer air into the houses on the higher levels.
Tredegar - - - (Monm.)	1870	Regis.-General's Return.	Bedwellty guardians -	*Mr. Radcliffe.* There had been a severe epidemic of fever, probably not less than 1,200 cases, mostly of relapsing fever, but with some typhus, in the past 12 months, in the families of labourers employed by the Tredegar Iron Co. Much overcrowding and very ill-constructed houses. Imperfect sewerage, and ill-kept privies and sewers, with insufficient water supply. Inefficient nuisance removal.
Trewalda - - - (Cornwall.)	1872	Regis.-General's Return.	Camelford guardians	*Dr. Home.* No drainage, privies, or system of excrement disposal. Polluted water.
Two Waters. (*See* Progmore.)				
Wareham - - - (Dorset.)	1872	Report from guardians.	Wareham guardians	*Dr. Home.* Enteric fever and ague. Water supply insufficient and mostly unwholesome. System of sewerage very imperfect. Great want of privy accommodation. No proper system for removal of refuse. Many houses unwholesome from overcrowding and want of ventilation, and unfit for the residence of human beings.
Warwick - - -	1870	Regis.-General's Return.	Warwick local board -	*Dr. Buchanan.* Prevalence of enteric fever. The public water supply of the town scandalously filthy. Sewers inefficiently ventilated. Unsatisfactory arrangements for refuse and nuisance removal.
Wath - - - (Yorks.)	1872	Local information.	Wath improvement commissioners. Rotherham rural sanitary authority.	*Dr. Ballard.* Enteric fever. Water supplied by company contaminated by sewage and other filth. Wells polluted. Want of drainage.
Wellington - - (Somerset.)	1872	Local information.	Wellington rural sanitary authority.	*Dr. Blaxall.* Epidemic of enteric fever. Water liable to pollution. Imperfect sewerage and drainage. No system for removal of refuse. Nuisances from manure, pigsties, and slaughter-houses.
West Auckland - - (Durham.)	1872	Reports from district medical officer.	Auckland guardians. West Auckland vestry.	*Dr. Harries.* Prevalence of enteric fever and diarrhœa. Recommendations of previous report of inspector only partly adopted. No proper water supply. Soil saturated. Privies insufficient and badly constructed. Wells contaminated by surface drainage. Nuisances and overcrowding.
Whitchurch - - (Hants.)	1872	Report from Guardians.	Whitchurch guardians. Ditto vestry.	*Dr. Thorne.* Enteric fever. Water obtained from wells sunk in porous soil saturated with sewage. No proper system of sewerage. Nuisance from piggeries. Overcrowding in badly-built cottages.

Places.	Date of Inquiry.	Ground of Inquiry.	Authorities concerned.	Inspector, and the chief facts reported by him.
Whitehaven (Cumb.)	1870	Regis.-General's Return.	Whitehaven local board.	*Dr. Buchanan.* Severe epidemic of true typhus. Enteric fever constant. Radically bad construction of the poorer quarters of the town, with much filth, destitution, and overcrowding. Wide-spread fouling of earth and air with excremental filth. Neglect by the local authority of many of its sanitary functions.
" 2nd report.	1871	Information of constant prevalence of fever and unsatisfactory answer from trustees as to action taken on report of last year.	Town and harbour trustees.	*Dr. Buchanan.* Sewer system incomplete and ill-ventilated. Neglect as to privy accommodation, drainage, and scavenging. Defective ventilation of courts and houses. Overcrowding.
Wigan (Lanc.)	1870	Regis.-General's Return.	Wigan local board	*Dr. Buchanan.* High rate of mortality, especially from fever and diarrhœa. Local want of sewer. Extensive nuisance from very ill-constructed middens. Want of privies and means of refuse removal. Bad construction and dirtiness of lanes, courts, and houses. Overcrowding. Inefficient sanitary inspection.
Wincanton (Som.)	1872	Regis.-General's Return.	Wincanton vestry. Do. guardians.	*Dr. Home.* Continued prevalence of fever, chiefly enteric. Foul privies and drains. Air and soil polluted by sewage. Cesspits; water supply from reservoir polluted.
Worksop (town) (Notts.)	1871	Regis.-General's Return. Report from Worksop guardians.	Local board	*Dr. Harries.* Scarlet and enteric fever prevalent. No proper water supply. Very bad privy arrangements. Numerous nuisances.
Worksop Union, without the district of the local board of health.	1871	Do.	Worksop guardians and various vestries.	*Dr. Harries.* Frequent prevalence of fevers and diphtheria. General sanitary supervision wanting throughout union. Almost everywhere want of proper water supply and due excrement removal. Gross neglect of matters in some places, and no system of isolation or disinfection.
Wycombe (Bucks.)	1870	Report of vaccination inspector.	Chipping Wycombe parish local board. Chipping Wycombe borough local board.	*Mr. Wagstaffe.* High mortality from scarlatina and other fevers. Drainage and sewerage defective. Serious want of privy accommodation. Water supply scanty, and largely contaminated by excrement. Combined action of the two authorities recently obtained.
Ystradgunlais (Brecon.)	1873	Regis.-General's Return.	Neath rural sanitary authority.	*Dr. Harries.* Serious prevalence of enteric fever. Polluted water. General want of privy accommodation. No proper means of isolating cases of infectious disease. No arrangements for removal of house refuse.
Ystrad-y-fodwg (Glamorgan.)	1870	Local information	Pontypridd guardians. Ystrad-y-fodwg vestry.	*Mr. Radcliffe.* Great prevalence of enteric fever. Extreme neglect of all sanitary precautions. No due provision for excrement or refuse disposal. Water supply insufficient and liable to pollution.

No. 2.

APP. No. 2.

Enteric Fever at Sherborne by Dr. Blaxall.

Report by Dr. Blaxall, on an Outbreak of Enteric Fever in the Town of Sherborne, Dorsetshire.

The town of Sherborne is situated in the north-west of Dorsetshire, and, according to the census of 1871, contains a population of 6,041. Agriculture forms the chief occupation of the male portion of the inhabitants; but there are three silk factories, which furnish employment to a few men and boys and to about 600 women and girls. Glove-making is also carried on by the women in their own homes. The Local Government Act having been adopted some years since, the sanitary authority of the town is the Local Board of Health, who, about a month or six weeks ago, appointed Dr. Williams medical officer of health.

Sherborne stands on the south side of a hill which rises to a height of about 140 feet, and is of oolite formation; its surface generally is covered with gravel, but in some places the rock crops out.

In 1867 Sherborne was visited by an epidemic of enteric fever, which caused six deaths; since then enteric fever has been endemic, and recently it has been again epidemic, as is shown by the following table of mortality :—

Year.	"Fever."	"Typhus."	"Typhoid."	Diarrhœa.
1868 - - - - -	1	—	—	5
1869 - - - - -	—	2	—	4
1870 - - - - -	2	—	2	6
1871 - - - - -	—	3	5	2
1872 - - - - -	1	—	1	2
The first 4 months in 1873 -	—	1	13	2
Total - - -	4	6	21	21

Sanitary Arrangements.

House accommodation is deficient, and overcrowding exists to a considerable extent. Many of the cottages require whitewashing and cleansing. No organised provision exists for the removal of house refuse, which is therefore suffered to accumulate in the neighbourhood of the cottages.

The removal of excrement is mainly effected by means of water-closets, many of which are in a very defective condition, and frequently one closet is used by three, four, or even more families. The water-closets are situated chiefly outside the houses, and are of two kinds; the one fitted with a cistern and ball-cock, and the other without any cistern. In the latter kind, water, when there is any, is supplied by a pipe which opens direct into the pan, and the water is turned on by means of a tap. The pan has a siphon-trap, which connects it with the soil-pipe. Many of the closets have no water laid on; in others, the tap of communication is broken or out of order. In the town are several privies with large pits, some open, others covered in, but all that I saw were in a filthy state, producing soil saturation and atmospheric pollution.

The sewerage and drainage are very inefficient. The channels used for carrying off slops and excrement are glazed earthenware pipes. Formerly the attempt was made to convey along these pipes the storm or surface water in addition to the sewage; the consequence was that the

contents of the drains burst through the traps, and flooded the floors of the houses situated in the low level of the town. Most of the surface water is now removed by an old drain and by separate pipes into the river. Sewage, with some roof-water, passes into the pipe system. The pipes appear to be still in some instances not sufficiently large for their purpose. Thus, a nine-inch pipe only is provided for the sewage of Cornhill, Newall, &c., and into this some four or five six-inch pipes open; these latter, themselves sometimes full, having also a steeper incline than the nine-inch pipe. The surface openings of the drains are usually trapped, and there are certain fixed ventilators to the sewers; but as there is a general complaint of the offensive smell arising from the drains and sewers, it would seem that the trapping must be defective or the ventilation insufficient, or probably that both these defects exist. Overflow and bath pipes appear, in some instances, to communicate directly with either soil-pipes or drains. In addition to these sources of danger, there are in the town remains of old sewers and dead wells, which give notice of their vicinity by the stench arising from them. I was present when one of these sewers was being opened and cleansed, and can therefore bear witness to its foul condition. In another instance I saw the floor of a house flooded with sewage supposed to have escaped from one of the old sewers; but the cause was not ascertained during my stay.

All the sewage of the town is emptied into the River Yeo, and causes great pollution of the stream.

The public water supply is derived from two sources. The first is in the valley at Castleton, about half a mile from the town, where a well is sunk to a depth of 130 feet; through the lower 90 feet iron tubes are passed, and as the water rises to the surface of the tubes, it is pumped up to the reservoir by the conjoint power of steam and water. The second source is a spring at Dymore; shafts are sunk, and the water is conveyed by a glazed earthenware pipe, laid at an average depth of 2½ feet below the surface, until it arrives at the valley, where the earthenware pipe gives place to an iron one, which is also carried underneath the ground until it reaches the reservoir, making a total distance of about one mile and a half. The water from both these sources together is called the Board of Health water. As delivered from the reservoir it is believed to be of good quality. The reservoir (which receives the water from both sources) is situated at an elevation of 140 feet, *i.e.*, a few feet above the houses of the highest level of the town. It is well-built, cemented, and properly covered in, and its overflow pipe does not communicate with any sewer. The water is conveyed from the reservoir direct to the town by a six-inch iron pipe, which is then extended by branches in every direction throughout the town; connected with these branch pipes are leaden ones, which distribute the water to various courts and houses, and also convey water to closet-cisterns, or direct into closet-pans. In addition to the public supply, there are several wells in the town, which are exposed to contamination from the soil, occasioned either by privy-pits, or by leakage from the old sewers before mentioned.

In the absence of service cisterns to waterclosets, it results from the above described relation of water-pipe to soil-pan that there is serious risk of water pollution. This will be illustrated in the sequel, when the recent distribution of fever comes under consideration. In one instance, where a cistern was provided, I observed that drinking water was derived from the overflow pipe of a cistern which supplies two closets, an arrangement that results in the water becoming exposed to any sewer air that may pass up the pipes leading to the pans of the closets.

History of recent Fever Epidemic.

The history of enteric fever in Sherborne, and of the present epidemic in particular, is highly interesting. As has been already stated, enteric fever was epidemic in 1867, and has continued endemic ever since, doubtless through the means of atmospheric pollution arising from foul privy-pits and from ill-ventilated sewers and defective drainage on the one hand ; and, on the other hand, through the water used for drinking having been contaminated by sewage or sewer air.

The accompanying table shows the progress of the recent epidemic :—

Number of New Cases of Enteric Fever.

In the month of	December 1872	2
"	January 1873	12
"	February 1873	15
In the week ending	March 8th	73
"	" 15th	45
"	" 22nd	28
"	" 29th	17
"	April 5th	17
"	" 12th	23
"	April 19th	2
"	April 26th	6
"	May 3rd	–
"	May 10th	3
		243

It will be observed that rather numerous cases occurred in January and February ; that in the first week in March there was a sudden and very great increase, and during the remainder of the month a gradual diminution. I made careful inquiry into all the conditions likely to affect the health of the community, particularly with respect to the supply of articles of general consumption. The influence of milk in the distribution could be excluded, but respecting the circumstances of the water supply the following facts were ascertained :—During December 1872 and January 1873 the water was frequently shut off from the town at a point near to the reservoir, and the same thing was done every night in February. It is known that when the water was thus shut off there were certain delivery pipes up which there was a rush of air immediately the tap was unscrewed. Now many of the openings to the pipes, as before described, are situated in the pans of the waterclosets. At night, after the closet had been used, the tap would be turned on for the admission of water ; none flowing, the tap in many instances would not be turned off again ; thus a direct passage into the water mains would be left open ; but the accidental circumstance of leaving the tap open was not required, as many taps were broken, and admitted a continuous flow of water during the day, but at night, no water being present, were uninterruptedly open to sewer air. Through these openings, during the night, air commonly passed from the closet-pan to the water-pipe ; in other words, the system of pipes for the water supply became the means of ventilating the closet-pans ; if a trap happened to be broken or out of order it became a means of ventilating the sewers ; and if a pan happened to be full of excrement, that excrement would be sucked into the water pipe. In January and February, when there were at least 27 cases of enteric fever in the town, closet-pans thus circumstanced were doubtless in some instances tainted with the specific *contagium* of

App. No. 2.

Enteric Fever at Sherborne, by Dr. Blaxall.

enteric fever; some may even have been filled with excrement from the bowels of fever patients. The sewer air which entered the pipes at night, when the water was turned off, would in the morning, when the water was turned on again, be driven forward, washing the pipe surfaces on which foul air had for hours been resting, and could hardly (even supposing no actual excrement to have got into the pipes) have failed to contain fever contagium; and this water went on, not only to cleanse closet-pans, but to be drunk by the people in the town.

I think it probable that the recent outbreak of enteric fever was caused by persons drinking of this contaminated water, and I base this opinion on the following considerations: first, the sudden appearance of so many cases in the first week in March, *i.e.*, after the water had been shut off every night in February; secondly, by the gradual diminution of cases after the first week in March, during which month the water was not turned off at nights; thirdly, by the manner in which the cases were scattered about the town; lastly and mainly, by the fact that the proportion of cases occurring amongst persons who derived their water from the Board of Health supply was much greater than amongst persons who had their water from other sources, as will be seen by reference to the following tabular statement:—

Houses in Sherborne, 1,010:—
  780 supplied with Board of Health water:
    whereof were attacked by fever, 148, or 19 per cent.
  230 supplied with other water:
    whereof were attacked by fever 13, or 5·6 per cent.
Persons attacked between December 1 and May 10:
  In the 780 houses, 226, or 29 cases per 100 houses.
  In the 230 houses, 17, or 7·4 cases per 100 houses.
Persons attacked in the first fortnight of March:
  In the 780 houses, 111, or 14·2 cases per 100 houses.
  In the 230 houses, 7, or 3·0 cases per 100 houses.

For the information on which the above statement is based, I am indebted to the medical practitioners of Sherborne, more particularly to Dr. Davies and to Dr. Williams, medical officer of health, who afforded me every assistance in their power.

Recommendations.

Having already furnished the sanitary authority with the departmental circulars on disinfection, &c., and recommended the measures to be adopted to prevent further spread of enteric fever, it remains for me to point out what is required to improve the sanitary condition of the town, and so provide against a recurrence of preventible disease:—

1. The law should be systematically enforced for the repression of overcrowding, and for the maintenance of all cottages in a cleanly and wholesome state. Dust-bins should be provided for the reception of house refuse, and public arrangements should be made for such refuse being periodically removed to some locality sufficiently distant from the town to prevent any nuisance to dwelling-houses.
2. In place of the present privies with large pits, some other method for excrement disposal should be substituted; all cesspools should be abolished. As there appears to be little or no doubt that a sufficient quantity of water can be obtained, the system of water-closets, already largely in use, would appear to be capable of

extension to all houses in the town, and to be the best adapted to its particular circumstances. The sanitary authority should see that all closets are supplied with water and kept in perfect working condition; that the soil-pipes of all closets are properly trapped and ventilated, and that each closet is supplied with a proper service cistern, so constructed as to give a proper flush of water, and to prevent any communication between the closets and the pipes which supply the drinking water. The number of waterclosets should be increased, so as to meet the necessities of the several families using them.

If waterclosets are not everywhere adopted, the authority must see that the means of excrement disposal are such as not to be a nuisance. The present pit-privies might be replaced by earth-closets or pail-closets, the authority undertaking the regular and systematic removal of the contents. For information on this subject see the departmental report on "Certain Means of preventing Excrement Nuisances in Towns and Villages."

3. The sewerage should be improved by the abolition (with proper precautions in the process) of all badly constructed or disused sewers and drains, and by the construction of efficient new sewers and drains wherever required. All sewers should be fully ventilated, so as to prevent the accumulation of sewer air, and means should be provided for periodically flushing them.

   Within houses all inlets of drains should be thoroughly trapped. Overflow-pipes from cisterns and waste-pipes from baths should not be in direct communication with any drain, but should be led over a drain entrance outside the house.

   Some means will have to be adopted for the disposal of the sewage, as it will not continue to be allowed to drain into the River Yeo.

4. The water supply should be increased, so that a continuous supply may be delivered; and great care should be taken to protect the water used for drinking and domestic purposes from all chance of contamination.

   All wells situated in the vicinity of drains, cesspools, &c., should be closed. In the central parts of the town there can be few wells that do not run risk of pollution from these sources.

5. A skilled engineer should be consulted as to the best means of improving the sewerage, and providing the town with a continuous supply of water, &c.

6. It is much to be desired that a permanent hospital should be established for the reception of persons suffering from dangerous infectious disease, in order that whenever a case appears, ready means of isolation may be at hand for such persons as cannot be properly lodged at home. On this subject the authority may usefully consult the departmental memorandum "On Hospital Accommodation to be provided by Local Authorities." In connexion with this hospital a suitable carriage should be provided for the conveyance of patients.

7. A proper chamber for disinfecting clothes, &c., should be provided, and other means of disinfection should be used about the persons and in the houses of people attacked by infectious fever. It is of particular importance that the bowel discharges of enteric fever patients should be duly disinfected before being thrown away.

P.S.—With respect to the rural district of Combe, a suburb of Sherborne, where enteric fever is endemic, it is important that the attention

of the rural sanitary authority, which is the Sherborne board of guardians, should be directed to the unwholesome conditions which abound in that neighbourhood :—

1. The water of "Combe Brook" is exposed to contamination from a privy built immediately over it, also from the droppings of cattle in the immediate vicinity of the spring where the brook has its origin, and from the drainage of Combe Farm.

2. In the neighbourhood of the cottages are large privy-pits, which cause the soil to be saturated, and the atmosphere to be polluted with excrement.

3. The large cesspool which receives the drainage from the closets of Mr. Mitchell's new houses is an abominable nuisance to the neighbourhood.

4. A filthy privy-pit extends under the footpath near the turnpike-gate, and is very offensive.

Steps should be taken to protect the water of the brook from contamination, the large privy-pits and cesspool should be abolished, and such a system of excrement disposal provided as shall not be fraught with danger to the public health. The report "On certain Means of preventing Excrement Nuisances in Towns and Villages" will give the authority suggestions for obtaining improved arrangements in the last-mentioned respect.

Enteric fever at Caius College, Cambridge.

No. 3.

Report by Dr. Buchanan on an Outbreak of Enteric Fever in Caius College, Cambridge.

In the town of Cambridge, since Midsummer last, enteric fever has been more than usually prevalent. In July one death from fever was registered, and six cases were admitted into Addenbrooke's Hospital from various parts of the town. In August three cases were admitted to the hospital, and in September two fresh cases were received into the hospital and there was one death in the town registered from fever. In October the disease became still more prevalent and fatal; especially, as the books of registrars and of the hospital show, in the neighbourhood known as Barnwell. In the three months, October, November, and December, the fever mortality in the whole registration district of Cambridge reached 15 out of a population of 30,000, being at the rate of 0·5 per 1,000 residents. The district has four registration sub-districts, and of these the sub-district of St. Andrew the Less was, after correction for the disturbing effect of the hospital, the one which in these three months had the highest fever mortality: here fever caused 0·69 deaths per 1,000 residents. In the other sub-districts, which have many sanitary advantages over St. Andrew the Less, cases were more scattered, and the deaths in the three months, including the deaths at Caius College, were at the rate of 0·28 per 1,000 only. The fever was at first wholly among the townspeople. In November it appeared in Caius College, and developed into the outbreak that is the subject of the present inquiry. But during the whole fourth quarter of last year, and up to the date of my visit (January 17–24) no other college has had any case of fever, unless a rumoured single case at Queen's be an exception.

In Caius College a case, the nature of which can perhaps not be affirmed with complete certainty, but which seems almost certainly to have been one of enteric fever, and, if so, the first case of the disease, occurred on the Library Staircase at the north-west angle of the college. The patient was a student who had come into residence on October 7, and his first symptoms date from November 1. The circumstance that at that date, and for a week after, there was no other case of enteric fever in the college, taken along with the circumstance that almost all the sanitary arrangements of this part of the college are distinct from those of the part afterwards and most severely attacked by the fever, lends support to the view taken by Dr. Paget and Dr. Bradbury, that the cause of that first case was not the cause which afterwards produced the more general outbreak. The second case of the fever, and here there is no doubt of the nature of the disease, occurred on November 8, on Staircase R, in Tree Court. The next cases were three, all on the same day, November 15, occurring in students living on Staircases O and S, and in the servant of a student on Staircase R, all of Tree Court. On November 18 a second student on the Library Staircase was attacked, and on the 19th a student living on Staircase N of Tree Court. From this time other students fell ill of the fever, some of them after the day of leaving college for the vacation, but all of them before the 1st day of December. The total attacks of fever among the students numbered 15. There was also one attack, before mentioned, and only one, among the students' servants. These students' servants live in various parts of the town, and between November 20 and 22 four attacks of fever in their

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Enteric fever at Caius College, Cambridge.

children came under medical observation: another child of a student's servant was attacked in December. No case of fever occurred in any Caius student living in lodgings in the town.

The following is a tabular statement of the number of persons of each class referred to, and of the number of fever cases among each class. The first section gives the facts for Caius College and its various parts; the second section for persons more or less connected with the college; and the third section gives some general data for comparison. This Table shows the attacks in each class during the three months, October, November, and December 1873. It has not been found necessary to exhibit here the fact of the Caius fever being in one of these three months only.

Occupying Rooms.	Persons.	Fever Cases.
§ I.—		
In Caius College - - - - - -	112	15
In Tree Court - - - - - -	63	12
In Gonville Court - - - - - -	17	1
In Caius Court - - - - - -	13	—
On Library Staircase - - - - -	8	2
In Master's Lodge - - - - -	11	—
§ II.—		
In town lodgings: students - - - - -	51	—
In town houses: students' servants - - -	34	1
" kitchen servants - - -	7	—
" housemates of students' servants -	60	5*
§ III.—		
In 105 houses in neighbouring streets - - -	(?)525†	8‡
In houses throughout Cambridge - - -	30,000	150§

* Five cases in three families.

† This figure is obtained by estimating five residents at each house whereat inquiry was made.

‡ This figure ought perhaps to be 9, but 8 having been obtained by the means of investigation adopted, it has been thought best to keep exactly to the results of that investigation, and not to correct them by other knowledge that could not be uniformly applied.

§ This figure has been obtained (in the absence of sickness records) by reckoning 10 cases to have occurred to every registered death. The estimate accords sufficiently well with the results of a private inquiry made at the end of November, when 46 cases were heard of in the town practice of 9 medical men. The Urban Sanitary Authority has had no medical officer of health, and it made no inquiry into the extent of the disease till the end of January. Then 9 cases only were returned as being under treatment in the town.

The main facts shown on this Table are—first, that the fever attacked Caius College with a very special incidence; secondly, that it has attacked the students resident in college, and not the residents in town lodgings; thirdly, that it has attacked various parts of the college with various degrees of violence.

The Rev. N. M. Ferrers, tutor of Caius College, has kindly investigated for me numerically the *a priori* probability of these and some other facts to which reference will be made in this Report, and has thus made more trustworthy the statements that will be made respecting the peculiarities of incidence of the fever.

1. As for any notion that the observed incidence upon the college may have been due only to the same causes that produced fever in other

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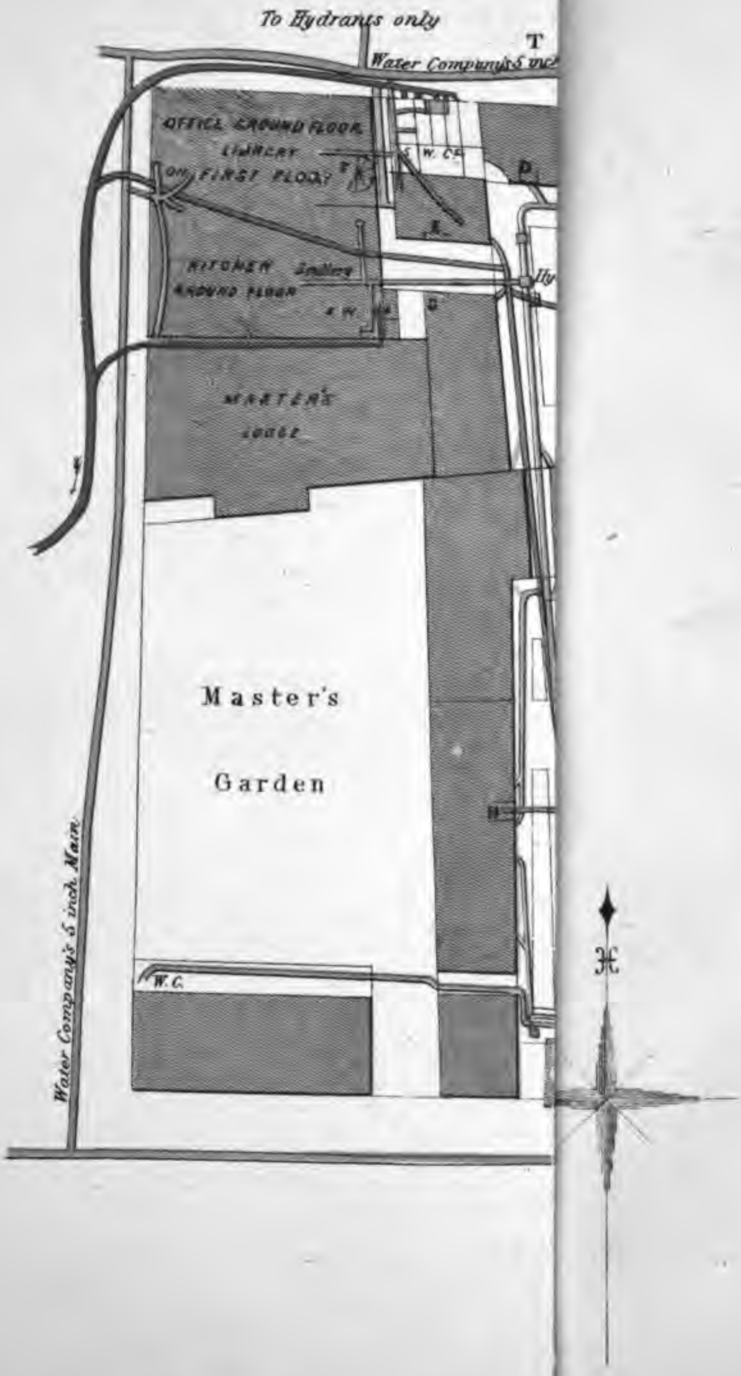

Places where water-supply can b

infected parts of Cambridge, it may be at once dismissed as entirely out of the question.

2. The incidence of 15 cases of fever being wholly upon the 112 students resident in college, and not at all upon the 51 students resident in town lodgings, makes it probable that the cause of the fever will not be found in any condition common to the two classes of students. Reckoned from the above figures, the chances that the cause will be found in some condition peculiar to the class of college residents are 375 to 1.

3. It will be seen by the Table that the distribution of fever in the several localities within the college has been very uneven. What follows on this subject, and in regard to causation, should be read with reference to the annexed ground plan of Caius. The several courts, "staircases" ("staircase" is the name for what is in fact a house, having a common stair, and a number of two-roomed tenements approached from the stair), and other parts are here shown, and the various drains, sewers, and water pipes in and around the college. Gonville and Caius Courts and parts to the west of them are old. The library and its staircase (F) in the north-west corner of the college were built some 20 years ago; but Tree Court (that is, all the buildings lettered from N to V, inclusive), with the portion of the central building north of the chapel (this portion being reckoned to Gonville Court) was erected only four years ago. Throughout the college a supply of excellent water from the waterworks company is delivered on the "constant service" plan; great care has been taken about other sanitary arrangements, and, except for casual oversights, they are excellent. But in the new buildings, at the time of their erection, such an amount of care and thought was bestowed upon the structural arrangements that it has appeared almost impossible for any injury to health to occur from mischances of sewers, drains, or water pipes. With an exception or two, to be discussed hereafter, the rule in Tree Court is that there is no sewer or drain underneath any part of any building; that there is no opening within any building to any drain; that the water-closets are isolated, of approved construction, and that every excrement-carrying drain takes the shortest cut into the environing sewers outside the college. The drains within the area of the court are mere pipes for slops and surface water, trapped in their course. And the rain-water pipes from the sides of the Tree Court buildings enter the sewers through 9-inch pipes, in each of which a trapping bend (commonly known as a "siphon," a misleading name, and not here used, as true siphon action will have to be spoken of) is provided.

In view of the special sanitary arrangements of Tree Court, it was not a little surprising and disappointing to observe the occurrence of case after case of fever here, and ultimately to find that out of the 15 cases of fever among the 112 residents in the whole college, no less than 12 were among the 63 residents in Tree Court. Now the chances against this event, as a matter of *a priori* probability, are 24 to 1, an odds so large as to make it necessary to seek the cause of the fever in some condition peculiar to Tree Court, and not operative or greatly less operative in other parts of the college.

In investigating the causes of enteric fever in Caius College, it has been necessary to hold all the foregoing facts in view, and to choose among various hypotheses of causation, that which best explains all the occurrences. In undertaking this task I was greatly helped by the fact that Dr. Paget, Regius Professor of Physic, and Dr. Bradbury, both of them physicians to Addenbrooke's Hospital, had gone over the ground

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of inquiry before me, and particularly that they had, after careful consideration, excluded several conditions that, *primâ facie*, had seemed causative of the disease. It appears desirable, however, in this Report, to discuss all conditions, whether or not they had been before considered, that can with any plausibility be regarded as causes of the fever, in order that the degree of credit to be assigned to each supposed cause may be represented in its due proportion.

The college is in a somewhat central part of the town, fairly elevated. Its soil is for 11 or 12 feet made-earth of the kind usual in old towns. Then follows a thin bed of dry gravel, exposed in digging the foundations of the new buildings, and existing probably at about the same depth over the whole site of the college. The only known exception to this gravel is a patch of clay of a few square yards at the south-eastern angle of the new building. Below these layers comes the gault clay. The foundations of the college reach down to the gravel and are all of concrete. This is very much the same kind of soil as other parts of the town in the neighbourhood of Caius.

Ever since July there had been an unusual amount of enteric fever in the town of Cambridge, and therefore no search was made for an independent *de novo* origin of it in Caius. It would have been impossible to certify with regard to any collection or derivate of excrement, or anything contaminated by excrement in Cambridge, that it had not had in it the contagium of enteric fever. The direction of inquiry, therefore, concerning the cause of an outbreak of this fever in November, has clearly lain in discovering how excremental matter of any description can have been presented to the lungs and stomachs of the persons attacked.

Searching through the college for conditions under which any such excremental matter can have been introduced, *Air*, contaminated by excremental products, comes first for consideration. Such air may be supposed to have conveyed the fever infection to certain students, either during their visit to water-closets or in their own rooms. It can hardly be supposed to have been more generally diffused than this, or some of the students living in town lodgings, who frequented the college by day, must have suffered.

The position of the various water-closets of the college is shown on the plan; those used by residents in Tree Court abut on the outer wall at the north-west corner of that court. All students' closets were found in good order and provided with efficient traps, the pipes from which pass into sewers in the streets around the college. Neither these pipes nor the outer sewers have means of ventilation; but in this respect the particular closets and sewers of and about Caius probably differ in no respect from the usual arrangements of good houses in the town. The closets for Tree Court are in an unwarmed, almost open, building; no bubbling up them is known to have occurred; and pressure of sewer air behind them, if there were such, would probably find readier means of relief than through the extra deep traps of these closets, well supplied as they are with water.

It may be suggested that the student living on the Library Staircase, and attacked on November 1, may about that date have visited, not only his own closet, but one of the closets assigned to Tree Court; that his visit to the former may, by leaving it specifically infected, have been the cause of fever to his neighbour using the same closet and attacked on November 18; and that his visit to some Tree Court closet may, by leaving some part of its structure specifically infected, have been the cause of fever to such students of Tree Court as afterwards visited that particular closet. Now, certainly, I have no data for deciding whether some accident of this sort did or did not take place.

Some such casual and temporary infection of a closet structure must be a matter of frequent occurrence wherever enteric fever exists. But experience tells us that, with anything like decent management of a water-closet, such an accidental infection of its structure is not followed by any series of events resembling those of November in this college. Hence I find it necessary to go further in search of some more special circumstance affecting the residents here.

As for the air of the students' rooms, so far as it enters by the door, it is the air of the staircase, where it were vain to seek for any excremental impurity, because, as before said, there is there no water-closet nor any sink or drain. Near the library staircase, indeed, a faulty drain was discovered in a coal cellar, but, as all the people employed in the kitchen, nearer to this cellar, escaped fever, the drain had probably no influence on more distant rooms. So far as the air of the students' rooms is admitted by the windows, it may, perhaps, have received, though with much dilution, some sewer impurity. Especially the suggestion has been made that rain-water pipes may have conducted sewer air into the neighbourhood of windows. In one place, again, by the library staircase before mentioned, certain rain pipes passed directly into and served to ventilate an excrement drain, conducting foul air from it to near a passage window of the staircase where the first attack occurred. In all other parts of the old buildings the rain-water pipes are connected with the slop drains within the court area. In Tree Court these pipes were arranged on another and a definite plan. Descending from the roof, and receiving on the second-floor level the rain from certain balconies, they passed down into special horizontal underground drains of 9 in. diameter, and these, always with a trapping bend near their ends, entered at several places into the foul sewers outside the college. It is asked whether some sewer air may not have bubbled through these bends, or whether in some way the trapping action of some one or more of them may not have been destroyed. The former accident may, here and there, under the conditions of insufficient ventilation of the sewers, perhaps have taken place, but it cannot be supposed to have occurred to any considerable extent or in any way peculiar to the college or to Tree Court. The latter accident is more important to consider, as the destruction of the trapping action would leave the upper openings of the rain-water pipes in direct open communication with foul sewers, and the supposed opportunity for foul air rising in quantity up the sides of the building might be thus afforded. Whether any emptying of the trapping bends did actually occur is a question that unfortunately cannot be answered, but the probabilities of its occurrence have been carefully thought out. First, the emptying of a bend is not likely to have occurred through evaporation, as the weeks at the end of October and beginning of November were cold and sufficiently rainy. Secondly, the emptying of a bend is not likely to have been effected by the aspirating action of any current in front of the bend, for the circumstances do not exist under which such action could be strongly exerted, and when it was most exerted (that is, when the street sewers were flowing rapidly with storm water) would be the time of best provision for keeping the bend full from behind. Thirdly, whether the trapping bend could on some occasion have been emptied of its water by a true siphon action, remains as a more difficult branch of the question. This occurrence must depend upon a variety of circumstances, and they are hard to formulate; among them are the calibre of the pipes, the rate and quantity of flow along them, the incline of various parts of the pipe system, the completeness of air removal from the lower part of the

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system, and, perhaps most importantly, the rapidity of cessation of the waterflow along the pipes. I have studied these circumstances as far as I am able for the particular case of the rain-water pipes at Caius during the period in question, and am disposed to believe (though I am not in a position to demonstrate) that here the trapping bends could not have been emptied by true siphon action.

Having regard, then, to every suggested sort of accident to the downspouts of Tree Court, it seems unlikely that they had any great amount of sewer air transmitted up them; and, as before observed, any such sewer air would, after its exit from the downspouts into the open air, be much diluted before it reached any window. On inquiry, further, as to the incidence of fever on the several stories of the new building, there does not appear much likelihood of foul air, conveyed in this fashion, having been a cause of the disease; for the attic and second-floor chambers of Tree Court, the chambers that had their windows nearest to openings in the downspouts, did not suffer more than the chambers on the first and ground floors, with windows away from any such openings.

Drs. Paget and Bradbury, who for a time had thought the hypothesis of atmospheric impurity the most plausible explanation of the facts, had, before my visit to Cambridge, recognised the unsatisfactory character of any such explanation; and had searched for other means by which the material of enteric fever could have been introduced into the college. The *Water* supplied to the college, being the same that is supplied to the greater part of the town, its quality having never been called in question, and the domestic supply of the college being on the "constant" system from the company's mains, was provisionally acquitted of blame, and the source of the college *milk supply* was diligently investigated. The premises of the milk seller were visited, but only ordinary cow-house faults were found there. There was no drainage nuisance, no water beyond the good water supplied by the company, and no person about the dairy had had fever. Still there soon appeared some *primâ facie* ground for suspecting the milk supply, in the circumstance that in the families of townspeople taking the milk of this dairy there had been a good many cases of fever. Out of an unknown number of people (but certainly more than 100 households) taking this milk, either directly or through Caius College, 16 attacks of fever were heard of at the end of November, and there might have been others not heard of. The exact significance of this circumstance as inculpating the milk could not be estimated; but, on the other hand, in opposition to the belief that the milk had played a part in the production of the fever, Drs. Paget and Bradbury pointed to the unequal distribution of the fever within the college, where all parts were supplied with the same milk, and they concluded that there was not sufficient evidence against the milk.

Making a fresh examination, on a somewhat different plan, of this question of *milk supply*, I had the assistance of Dr. Bradbury and of Mr. Harle, of Addenbrooke's. Mr. Harle kindly inquired throughout certain streets in the same quarter as the college, and gave me notes on 105 houses, as to their milk supply and as to any fever in them. He was informed that last October and November 13 houses got milk from the same dairy that supplied Caius, and 92 got milk from various other sources. Of the 13 houses three, he was told, had had cases of fever; of the 92 he could only hear of five that had been attacked.

It must be premised that the data themselves were known not to be precisely accurate, that at one house fever was denied and at another the fact of

two milk supplies being taken was suppressed, and so on. But this particular knowledge came from a special source, and could not be applied to correct the whole of Mr. Harle's results. And it was thought that worse fallacies might be introduced by making partial correction than by leaving the whole results just as Mr. Harle procured them.

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Plainly there arises out of this inquiry a probability that the milk may have been at fault. On the other hand, consideration of the unequal distribution of the fever throughout the college constituted, as Drs. Paget and Bradbury had pointed out, a probability that the milk supply, a condition common to the whole of the college, was not at fault. I ascertained that all the college supply at each delivery was brought to the college gate in a single "tank," and was distributed by the same cans (refilled from the tank as often as necessary) throughout the various parts of the college. The milk, therefore, as supplied to the one or the other court, must have been everywhere exactly the same; yet, in the distribution of the fever, persons living in one (Caius) Court wholly escaped. In deciding the amount of the one and the other probability, I had the advantage of Mr. Ferrers's aid, and find that the chances for and against the milk (so far as they rest on the foregoing data) are almost exactly balanced, being about as six to one on each side.

There is, however, much more important evidence forthcoming about the milk than is afforded by these comparatively small and conflicting probabilities. In a previous reference to the circumstances of resident and non-resident students, I have quoted Mr. Ferrers's calculation that the chances were no less than 375 to 1 that the cause of fever did not lie in a common condition shared by the residents in college with the residents in town lodgings. Now, the milk from the same dairy is supplied direct from the dairy to both classes of students; there is no reason to suppose it is anywise different as delivered to the one and to the other class. This evidence is, to my mind, conclusive as acquitting the milk; for whatever were the small presumptions against it, arising from the earlier inquiries, and now from those of Mr. Harle, they are wholly thrown into the shade by the consideration of the last-mentioned enormous degree of probability that it played no part in the fever.

All the more usual ways of enteric fever spread have now been considered, and none of them have appeared adequate to account for the intensity of incidence of fever upon Caius College, or for its remarkable incidence on Tree Court. Holding always in view the special character of these occurrences, let us refer again to the plan, and observe that the *water supply* to the college is taken from a surrounding 5-inch main at six different places, and that one of them, at the Gate of Humility, is for Tree Court, and for no part but Tree Court. What if there should be something wrong with this one local supply?

Even *primâ facie*, there is something to be said for this view. The suddenness of the outbreak in the college was such as at once to suggest to Drs. Paget and Bradbury, and equally to myself, "the thought that it might be due to contamination of the water or milk." The area of the particular water distribution is exactly the area of the fever, at least of 12 out of 15 cases, one or more of the remaining cases requiring probably no explanation beyond every-day circumstances. The good character of the company's general water supply would not avail as an argument against a local contamination in a local service. And at an early period of my investigation I was struck with the circumstance that while every watercloset in the old part of the building was provided with a cistern proper to itself, the closets in the Tree Court buildings

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were supplied with water direct from the high-pressure constant-service pipes.

Supposing, I asked myself, that the water of the particular service to this court had, through a direct connexion with some closet, at some time got mixed with watercloset or sewer air drawn into its pipes, had we not here, in Tree Court and not elsewhere, a repetition, at least in essentials, of the conditions to which, at Sherborne, my colleague Dr. Blaxall last year distinctly traced contamination of water and consequent enteric fever of a very wide-spread and intense kind? I remembered, too, that Dr. Blaxall's observations were in accord with some experiences published about the same time by Dr. Carpenter, of Croydon.

In following up this clue, some very interesting and suggestive considerations soon appeared.

1. As matter of fact, most of the students' servants about the college, and notably those of Tree Court staircases, spoke of the occasional absence of water from their pantry taps. In Tree Court two or three servants said that after such an absence the water would come on "with a vengeance," "like soda water," evidently having become mixed with air with which the pipes had become charged. The failure of water was mentioned by some servants as occurring once a month or so; by others as being more frequent; and the servant having charge of the first floor and higher floors of Staircase O spoke of it as a thing that happened two or three times a week. Whence the air in these pipes may have been derived will presently be matter for consideration.

2. Under a really constant system of high-pressure water-service it is plain that pipes could not have thus got filled with air. Perhaps a considerable weakening of pressure, not going to the extent of intermission, might have stopped the supply at high levels; and there were particular circumstances to weaken the pressure in Staircase O, and these doubtless account for the more frequent lack of water here. But real intermission of supply must have occurred to account for the phenomena described. And this intermission must have gone to the extent of allowing the whole horizontal service main of Tree Court to have become emptied of water, if any hypothesis of mischief resulting from this air in the water pipes is to be upheld. For the fever attacked every staircase of the court from N to U.

3. Complete intermission of supply was found to have actually occurred on two occasions at least during the last term. The earlier occasion can be defined as the evening of the second day of an October frost; and, thus far might have been either on October 25th or on October 30th, but other associations suggest October 25th as being the more probable of the two days; on this occasion only the particular service through the Gate of Humility was stopped. The later occasion was when the water company's servants having, for purposes of pipe repair, cut off the water supply of some half of Cambridge, there was hurrying to restore the supply in order to gain water power to blow the organ of King's College Chapel for a musical service. This fixes the date of the second known intermission at about half-past 10 a.m. on All Saints' day, November 1st.

4. Now a fortnight is about the incubation time of enteric fever. A fortnight after October 25th is the date of the first attack in Tree Court. A fortnight after November 1st is the date of the second, third, and fourth attacks. And though it was known that other cases of fever kept dropping in till the end of November, the coincidence of the early fever with these ascertained intermissions was not the less suggestive as indicating the direction that further inquiry should take.

It has just been said that any hypothesis of harm coming from air mixed with the drinking water of Tree Court cannot be satisfied unless the whole horizontal service main of the court can have been emptied, An apparent physical obstacle to such emptying of this main was indicated by the water company. Admitting that the pipes of any particular staircase can be emptied, viz., when an upper and a lower tap are at the same moment open, the company points to certain taps (which I shall call "valve-taps"), that are placed on the water pipes at the bottom of every branch to every staircase, and elsewhere on water pipes in the college. These valve-taps are of peculiar construction. Their first object is to allow the supply of any particular sub-service to be cut off, and this is effected by a screw action. But when the valve-tap is completely open, it will not allow, or rather is not intended to allow, passage of anything along the pipe except in one direction, from the mains to the place of use. A plug placed inside the valve-tap and acting by gravitation, is the means by which the result is attained; and certainly, when one tests such a tap by blowing first into one end and then into the other, while the tap is open, it is found to give passage to air in one direction only. It was held, therefore, that the existence of these valve-taps at the foot of all staircase pipes would prevent any back flow of water or air into the horizontal main. Now to this it might almost be enough to oppose the experience of the servants respecting the quantity of air found in the pipes after an intermission of supply, but it was seen that if they had exaggerated the quantity, the air observed by them might have been merely what had got into the particular staircase pipe during an intermission of service, and the tap at the foot of the staircase might still, by its automatic action, have effectually prevented any back flow of air into the horizontal main. The question was put to the test of experiment, with the kind help of the water company. While the pantry tap on the topmost floor of Staircase P was being kept constantly open, and the taps on other floors of the staircase kept shut, the whole of the water mains in and around the college were emptied at hydrants and elsewhere. If the automatic valve-tap at the foot of the Staircase P had done its duty, obviously the water would have been held up in the pipe of that staircase. But in fact it was found that as soon as water ceased to flow from the high-level pantry tap, air was sucked into it with considerable force, and on proceeding to turn other taps at lower points of the staircase, not a drop of water escaped, proving that the water had all passed backwards through the supposed automatic valve-tap into the horizontal main, and that this tap had not had the slightest influence in preventing the accident which it was designed to prevent. In justice to the principle of the valve-tap, however, it must be added that this particular tap was laid on its side in such a way that gravitation could not move its internal plug. This blunder had perhaps been made elsewhere, but the fact of this particular valve-tap on the service pipe of Staircase P offering no obstacle to the reflux of air into the horizontal main, will hereafter be seen to have a special importance.—On restoring the water supply, water mixed with air rushed out of the top pantry tap with much force and splashing.

It must be remembered how Drs. Paget and Bradbury saw, in the circumstances of the particular outbreak in the college, reason for suspecting that the fever poison had been introduced by some article of drink, and it must be admitted that of an equal number of persons drinking dangerous water and breathing dangerous air, the former are likely to suffer in the larger proportion. Although, among the users of some particular well in Cambridge, a special incidence of fever may have existed, yet, *among people taking the company's water*, it may be almost certainly affirmed that nowhere in Cambridge was the same sort of risk incurred as at Caius College for dangerous matters getting introduced into drinking water.

It is the rule with the Cambridge Water Company to supply water-closets, not directly from the high-pressure pipes, but from an interposed cistern or service box. This arrangement, besides preventing waste of water, has the following advantages: that, if there should ever be any foul vapours from a watercloset, and these should under any circum-

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stances pass through the closet supply valve, their passage backwards along the water pipe must be interrupted at the cistern or service box. The omission of this arrangement, on the other hand, affords a risk of such vapours passing directly into other parts of the water system, if they should succeed (on occasions when the closet valve is opened during intermission of water pressure) in passing through the supply valve of the closet. At Caius College this risk was run, and it will presently be seen that air from a watercloset, passing through the valve on the service pipe, had opportunity of reaching other pipes which supplied drinking water.

The rule that every watercloset shall receive its water supply through a cistern or service box is so generally observed in the colleges and houses supplied by the Cambridge Water Company, that at my first visit to the town, I found the company was unaware of any exceptions to the rule beyond those at Caius College. I afterwards found two other institutions where there was similar direct supply, and these will hereafter have to be mentioned. But for the present it will be sufficient to say that in them there was not the same sort of risk as at Caius for dangerous matters getting introduced from waterclosets into drinking water.

It has been said that Tree Court and Tree Court only, out of Caius College, presented the arrangement of waterclosets served direct from the high-pressure pipes. In the other parts of the college, the waterclosets were provided with cisterns or service boxes in the way usual in the town at large. Hence Tree Court was the only part of the college that ran the risk incidental to the omission of these arrangements.

The closets of Tree Court are (*a*) those, before spoken of, at the north-west corner of the court; these have no interest for us as affecting drinking water in the college, since they are served directly from the 5-inch main in the street, by a branch which furnishes no drinking water to the college. And (*b*) two closets within the Tree Court buildings — closets directly connected with the service that enters through the Gate of Humility, and that furnishes drinking water for every staircase of the court, beginning with Staircase N, and ending with Staircase V. One of the two closets now under consideration is situated in the basement of the porter's lodge, the other on the first floor of Staircase P.

It is the last-named closet on which interest chiefly centres. It is some 30 or more feet of vertical distance above the level of the horizontal water main of Tree Court, and some five or six more feet above the level of the closet in the basement. This elevation obviously must have given particular facility for the entry of air into the service pipes of the Staircase P closet. When the pressure of water was intermitted, the supposed automatic valve tap at the foot of Staircase P failed, as we have seen, to fulfil its intention of preventing air from entering the horizontal main. On such an occasion it only needs the water valve of the upper closet to have been open or leaking, while in the basement the water valve of the closet or the tap over the adjoining sink (a screw tap and very liable to be left open) was also open or leaking, in order to cause the entire horizontal main of Tree Court to have become filled with air containing watercloset vapours, afterwards to be delivered in drinking water.

For the better understanding of the physical circumstances that may have operated to allow watercloset air to enter the Tree Court water system, particular examination has been made into the details of construction of the two waterclosets, and particularly of the upper one.

Both the closets now being considered must be suspected of having assisted, though probably in different ways, to a contamination of water in the Tree Court main. The chief way in which the lower closet and its adjacent tap would be likely to be mischievous on occasions of intermission of water supply would be that while they were open (as, from the facts about Staircase O, as well as from my own observation, it is certain they often were), they would permit exit of water from the pipe system of Tree Court, and consequent entrance of air into this system. This would occur whenever, under such circumstances, an opening was made at a higher level. In this way the whole horizontal main of Tree Court, between such higher opening and the basement closet, could be filled with air; and the effect of afterwards recharging this main with water would be to distribute the air, along with anything that was harmful in it, to every staircase of Tree Court. It is, I think, pretty certain that air from the basement closet itself could not have entered the water pipes through the half open water-valve, for there was no column of water at a lower level to draw air into the service pipe; and the arrangement of that pipe was such that air can hardly be supposed to have bubbled inwards into it, while water was trickling outwards through the water-valve.

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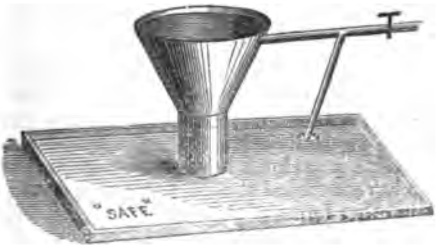
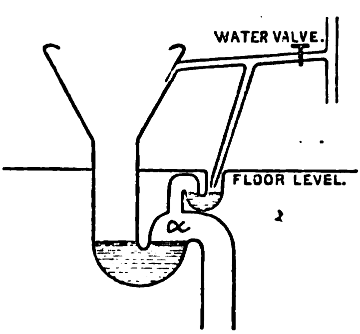
The upper closet would probably play a more direct part, for it would certainly allow, when its water-valve was moved during times of intermission of water supply, free entrance of watercloset air, in replacement of the water between its own level and the basement. The woodwork of Staircase P closet had been removed before my first visit, and the arrangements shown in the following diagram (A) were exposed to view, an ordinary tray or "safe" being



on the floor level to catch an accidental splash or leakage; and a small pipe, the function of which was not at first apparent, leading from the service pipe to a hole in this "safe" after the manner here shown. The workmen who had removed the woodwork spoke of there being some filth (which they supposed to be excremental) in the "safe" in the neighbourhood of this hole. For the better understanding of this arrangement I had the "safe" removed, and found the closet to be of the S-bend pattern with details as shown in diagram (B). The small pipe from the water service was found to dip about three quarters of an inch into the hole that had been seen in the "safe," which hole was the commencement of a smaller S-bend pipe, provided to drain the safe (in case of



its being flooded) into the top of the great S-bend in the excrement pipe. Now from the unventilated sewer in Trinity Street, up to the point marked *a* in this diagram, there is not a single opening nor a single trap; nothing, either to get

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rid of, or to attempt to keep back, the foul air. Due charges of water in the two traps were relied on to keep this sewer-air out of the general atmosphere of the building. It is intended that the closet, being in use as frequently and in the exact way that is expected, shall have its large trap kept filled by water down the pan, and the small trap kept filled by the small "weeping-pipe" that dips into the hole of the safe.

Now, assuming a closet of this construction to be in daily use, sewer air, as such, is not likely to pass through the great S-bend; though it is sure to become dissolved in the water of that bend, and to be given off, along with anything volatile it may have brought from the sewers, from the surface of water exposed at the bottom of the pan. But through the little S-bend it is not only in this way that we should expect air to pass from the sewers into the neighbourhood of the water pipes. A very small excess of atmospheric pressure in the downsoil pipe over the interior of the house would cause sewer air to bubble through the little bend; or some aspirating or siphon action, such as I think would be liable to occur, would empty this bend of its water. Sewer air, as such, finding its way to the water pipes would probably be more dangerous than sewer air that reached them after having been absorbed by and evaporated from water; for the latter sort of air could only contain volatile impurities, while the former would contain particulate elements as well; and it is probably in such elements that any specifically injurious quality of sewer air resides.

[If the closet be for any length of time out of use, the water of these traps evaporates, and is not resupplied; and so the whole staircase is in direct atmospheric connexion with the sewer. Probably this went on in the midsummer vacation, and was the cause of a stink observed on Staircase P, while this closet was locked up and deserted. But it is with no such accident as this we have to do. We are in search of some risk to the whole Tree Court *water* system through the operation of the closet.]

[In criticizing, as above, the construction of the Staircase P closet, I think it just to observe that that closet did not form part of the original plan of the new buildings at Caius, but was inserted while they were approaching completion; and further, that I learn on good authority that closets of this construction and others involving the same principles have come into increasing favour with many plumbers, who have regarded them as combining several sanitary requirements not attained in other forms of closet.]

It has been shown how readily the water pipes of the Tree Court may have got filled with watercloset air through the valve of the closet on Staircase P. From the construction of this closet, it is now seen that any such watercloset air *must have been essentially sewer air*, air from the pan containing sewer emanations coming through the water of the great S-bend, and, more importantly, sewer air (probably delivered exactly in the state in which it existed in the sewers) passing through the little S-bend up the weeping-pipe. Possibly too, not air only, but some liquid foulness may have been drawn up the weeping-pipe; for it dipped (as has been said) some way into the little S-bend, and hereabouts (we know from the workmen who first opened the closet) some filth was found. It is stated that a very rapid discharge of water down the closet-pan is apt to splash some of the liquid of the great bend (from the point marked *a*) up into the small S-bend, and even into the "safe."

Once again, any sewer emanation that is here in question may have had a specifically dangerous quality. As before said, no assurance can be given that this quality did not exist after July in any derivate of excrement in Cambridge. But we know more than this respecting the particular sewer into which the Tree Court closets discharged; we know that last October that sewer was actually contaminated, as it is not known to have been before contaminated, *with the specific matter of enteric fever*. "A short time prior to the appearance of fever in the college," Drs. Paget and Bradbury write, "cases [of enteric fever] occurred in houses on King's Parade and Freeschool Lane. . . . The town sewer, into which these houses are drained, passes along Trinity Street, so that the excreta of the fever patients must have been passing along

the sewer which runs parallel to the long front of the Tree Court. If, therefore, any emanations from this sewer could gain access to the college, they would be an abundantly sufficient cause of an outbreak of fever."

Later on in this inquiry, I thought it desirable that pieces of the water-pipes of Staircase P closet should be subjected to more minute, and especially to chemical examination. It was found that the outside of the end of the weeping-pipe, where this dipped into the small S-bend of the safe, was crusted with a brownish matter, uniformly, and as if gradually laid on; and this pipe and the supply pipe (taken from between the weeping-pipe and the water-valve) had inside them some little deposit not remarkable in its aspect. Dr. Dupré having these pieces submitted to him with a rough statement of the physical circumstances, was asked to make such an examination of them as he judged best, in order that an opinion might, if possible, be formed as to the presence of any fæcal product in the deposits, and he has given this significant report:—

"I. *Deposit inside the pipes.*—I cannot detect a trace of sulphide, and there is therefore no proof of the action of sulphuretted hydrogen. On the other hand the deposit, both in the supply pipe and in the small weeping pipe, contains a large proportion of nitrogenized organic matter and an appreciable amount of phosphoric acid, both of these in much greater proportion than could possibly be derived from the water used. It would seem, therefore, that *water* impregnated with fæcal matter must have entered these pipes and so helped to produce these deposits.

"II. *Deposit on the outside of lower end of weeping-pipe.*—In this deposit also I cannot detect any sulphide; but it contains, like the other, a very large proportion of nitrogenized organic matter, and a very considerable proportion of phosphoric acid. I cannot doubt, therefore, that this deposit is derived from water strongly impregnated with fæcal matter."

In Dr. Dupré's first paragraph I have put the word "water" in italics. His results show first, that (as circumstantial evidence had appeared to indicate) excremental matter actually has entered the water pipes of staircase P closet; and secondly, that it has in fact (what has before been suggested as a possibility), entered the water pipes as *a liquid.* In no other way can the presence of phosphates in the interior of those pipes be accounted for.

The "water impregnated with fæcal matter," of which Dr. Dupré speaks, came then from the closet traps, probably wholly from the little one in the safe. The trapping *water,* then, has been sucked into the water-service pipes. This has consisted of ordinary water-closet washings, but with the addition of anything it had absorbed from the sewer air with which it was in contact. So that if the consideration be of importance, it is now further seen that last October, *not only in air but actually in water,* fever poison may have entered the water pipes of Tree Court.

Attempts have further been made to learn something of the actual use of the Staircase P closet during October and November. As the closet is a private one, some interesting facts concerning it were almost beyond expectation available. It happened on a particular day, and in the evening of the day that something seemed wrong with the closet, for water did not flow into it after use. This day can be fixed as being in the latter half of October. The 25th was, it is believed, the day on the evening of which the service of Tree Court was cut off. The porter remembers that when he had cut off the water service on this evening he went down to his basement tap and collected there from all the water he could get for use till the service should be renewed. It is perfectly likely, therefore, that on October 25 there was a combination of conditions closely resembling those which I contrived (p. 7) in my experiment. Air was sucked into the pipes and distributed with the drinking water on both occasions;

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but on the October occasion this air was sewer air derived from the watercloset, and along with it, we may now believe, went some specifically infected liquid from the same source.

It is not, I think, possible to determine all the occasions when combinations of conditions, similar in essential respects to those of October 25, may have taken place, with the result of befouling the drinking water of Tree Court. Intermissions more or less complete of water service in that court would appear not to have been uncommon, and the circumstances of them are not now ascertainable. I have mentioned November 1 as one day when a complete intermission is known to have occurred, and have noted as a suggestive coincidence that the second, third, and fourth attacks of fever in Tree Court happened just a fortnight after. But I would not venture to affirm the exact relation of each water intermission to each case of fever. It is uncertain, for example, whether on November 1 anyone had access to the closet on Staircase P, and it is apparent that (if the closet-valve there did not leak, and there is no evidence of it having done so), there must have been somebody to move the valve of that closet in order that the particular mishaps of October 25 could have been repeated.

[It has been asked me why, if the closets in Tree Court buildings could have done harm by their relation to the local water service of Tree Court, those same closets, and also the closets at the north-west angle of the court, should not similarly have done harm to the district of Cambridge supplied by the outside 5-inch main, into which air from these various closets might be supposed to have got; if not at other times, at any rate on November 1, when not only one branch of the college water service, but the service of a very large adjacent area of Cambridge, was cut off. The question is an important one, as affecting the reasoning here adduced as to causation, inasmuch as the entry of sewer air into the 5-inch main should, on the present hypothesis, have been followed by fever outbursts elsewhere than in Tree Court—in other parts of Caius, in Clare College, in Trinity Hall, and other places, in most of which no case of fever was seen. The answer to the question is, however, clear. The engineer of the water company tells me that on November 1 no hydrant was open to drain the main; and even if one had been opened in the neighbourhood of Caius College it would have been impossible for the 5-inch main to have become emptied except after a considerable length of time, as there were several miles of pipes full of water at a higher level than the pipes surrounding Caius. In fact it was for a very short time only that the main service was cut off; long enough no doubt by removing the pressure to put a single service into the same condition as if its own junction with the street main had been severed, but not long enough to allow even a partial emptying of a street main fed by reflux of water from miles of pipes just above its own level. The physical conditions of the larger 5-inch main service were therefore different from the physical conditions of the particular Tree Court service, and no opportunity was given for the 5-inch main to get filled with air, either from sewers or elsewhere. The difference is represented, however, as being in some respects a question of time, and it is easy to imagine circumstances of open hydrauts and longer intermission of service under which a much wider diffusion of fever might have happened in Cambridge—if the present hypothesis of its production at Caius be well founded.]

[I have, in a previous paragraph, spoken of two public institutions which have their closets supplied without the interposition of cisterns or service boxes, direct from the main, after the fashion of the closets in Tree Court. In neither of these institutions had there been any fever, and it was therefore with much interest that I examined the arrangements of these closets, to see how far they corresponded with those of Tree Court. In one of these institutions there are two closets in the basement, with construction and arrangements closely resembling those of the basement watercloset of Tree Court, of which closet, it will be remembered, I have written that it is very unlikely to have allowed air to pass backwards through its valve; and in this institution there was no closet at any higher level—nothing corresponding to the closet of Staircase P at Caius College. In the other institution there is a large group of closets of the same construction and arrangement as in the new closets at the north-west angle of the Tree Court at Caius; they have not had the opportunity, any more than the corresponding closets of Caius, of befouling any water

service. But there are here three closets on first-floor levels inside the building, served directly from water pipes which also supply some persons with drinking water. Special interest attaches to these three closets as regards their similarity to the closet on Staircase P of Caius, or their dissimilarity from it. They prove to be all of the same construction one with the other, and all in some essential respects different from the Caius closet. There is no "safe" to them, and therefore no weeping-pipe. They have traps of the D pattern, and in the trap there is no opening which would give exit of sewer air into the neighbourhood of any water pipe, or up which the trapping water could be splashed. The soil pipe is very amply ventilated below the closet trap, and between the foot of the soil pipe and the junction with the public sewer, first a trapping bend, and then a ventilating opening is placed. Of such a watercloset I would not certify that, on occasions of intermission of water supply, air might not be drawn from the closet pan into the service pipe; although, as automatic valve-taps, properly placed, are provided in connexion with the service pipe, this occurrence might not take place. But besides that the special risk of the weeping-pipe arrangement is absent, I would venture to affirm that if watercloset air was ever drawn into the pipes, it could not by possibility be *sewer air* in the sense that air from the watercloset on Staircase P of Tree Court must necessarily have been sewer air.]

There seems, then, ground for believing that on some occasions, under particular conjunctures of circumstances, excremental matter containing fever poison entered the water pipes of Tree Court, and was delivered along with the drinking water of the court. In this hypothesis, and in the course of the evidence that has been adduced in support of it, will be found a coherent explanation of the chief facts of the outbreak. We account for—

1. The special incidence of the fever on Caius College, and on the students resident there, as distinguished from the students living in town lodgings.
2. The special incidence of the fever on Tree Court, and its affecting all staircases and levels of Tree Court.
3. The date of the commencement of fever in Tree Court.

We have also perhaps accounted for other phenomena. For (4) if, as some competent judges contend, the incubation time of this fever may vary within somewhat considerable limits, not only the earlier attacks in Tree Court students, but some number of later ones, may be referred to *one or two* accidents of the sort discussed; possibly, some of such judges would say, even the whole of the attacks; though I should myself regard the latest attacks as more probably due to some repeated (if unknown) introduction of the fever poison. (5) A probable explanation is afforded of fever attacks in two out of three of the families of students' servants (see Table, p. 64); for very probably the jugs in which these two servants working in Tree Court sent home (as they were permitted to do) milk to their children were rinsed out with the same water that was used by the students. In these two families the attacks were nearly simultaneous with the group of attacks of November 15 in the college. To the extent of four cases in these two families, moreover, the relations which at one moment appeared significant as between milk and fever (in 16 cases) may be otherwise explicable. [Students resident in town lodgings received their milk direct from the dairy, as before said, and not through the college.] (6) The student who contracted fever while living in Gonville Court (Staircase G) frequently visited a student, who was attacked about the same time by fever on Staircase P, and he may thus have been subjected to the cause of fever special to Tree Court.

Reviewing, as judicially as possible, the whole history, both the facts of the outbreak and all suggested explanations of them, I am disposed to think the introduction of the fever, and the phenomena that were special about it—in fact for Caius College, *the cause* of the outbreak—*has lain in contamination of a particular section of the college water service.* I would not be understood to affirm that every case, even of

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those in Tree Court, was directly due to that one cause and to no other; but it would be safe to presume this, I think, for the great majority of the attacks. The apparent inadequacy of a cause so small and occult to explain such a large and crying misfortune will be to some people, I should suppose, a hindrance to an acceptance of this judgment. But in the pathology of enteric fever and similar diseases we know that a very minute quantity of infectious matter can, under favourable circumstances of distribution, produce very large and intense results. And, moreover, the present case does not stand alone as an instance of the spread of enteric fever by means of a so-called constant water supply that in practice has intermissions in its service.

At the time of my visit to Cambridge I found that means of ventilation, apparently efficient and safe, were being applied to all the college drains, and that all minor hazardous or suspicious conditions which had fallen under notice were being actively remedied. And now structural changes have been made by which, in every part of the college, it will in future be impossible for any drinking water to become impregnated by sewer air in the way in which it is here judged to have been impregnated last year. Special cisterns or service boxes are being put to every water-closet where they were before wanting, so that no closet will henceforth be supplied from any drinking water pipe, and therefore there cannot henceforth be any suction from any closet into any such pipe. After a very minute examination of the college, no other precaution suggests itself to me as being required.

In conclusion I must express my grateful sense of the assistance which I had from every one whose help I had occasion to apply in Cambridge. But very particularly I must record my thanks to the Rev. John Lamb, bursar of Caius College, for his incessant and laborious co-operation, to which this Report owes the greater part of what it may contain of value; to the Rev. N. M. Ferrers for his valued mathematical assistance; and to Drs. Paget and Bradbury for their important counsel and kindly criticism.

NOTE.

The following regulations indicating the right method of supplying water to waterclosets in a place where the so-called "constant service" plan of water delivery is in use, are extracted from the "Regulations under the Metropolis Water Act, 1871." These regulations, having for their object the "preventing of undue consumption or contamination of water," are the result of an inquiry made for the Board of Trade by Lord Methuen, Captain Tyler, and Mr. Rawlinson, C.B. They have the sanction of the Board of Trade, and may be put in force by the London Water Companies:—

"20. *Every* boiler, urinal, and *watercloset*, in which water supplied by the company is used (other than waterclosets in which hand flushing is employed), *shall*, within three months after these regulations come into operation, *be served only through a cistern or service box*, and without a stool-cock, *and there shall be no direct communication from the pipes of the company to any* boiler, urinal, or *watercloset*."

"24. *No pipe by which water is supplied by the company to any watercloset shall communicate with any part of such watercloset, or with any apparatus connected therewith, except the service cistern thereof.*"

No. 4.

Report by Dr. Ballard upon an Outbreak of Enteric Fever at Armley, in the Borough of Leeds.

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In the early part of the month of August information was received by the Local Government Board of an outbreak of enteric fever having occurred at Armley, a suburb of the town of Leeds, accompanied by an intimation that public rumour attributed it to the use of one particular milk supply; and I was instructed to proceed at once to its investigation. On my arrival in Leeds, I sought an interview with Dr. M. K. Robinson, the Medical Officer of Health of the borough, within which the township of Armley is situated. I found that Dr. Robinson was quite aware of the fact of the outbreak, and that he had already commenced an inquiry into the cause of the fever. The inquiry instituted by him, however, was not so far advanced as to render mine unnecessary, and he immediately placed all the information in his possession at my disposal. During the whole time that my investigation lasted, Dr. Robinson and the officers under him gave me their personal assistance, and I am bound to express here my sense of the high value which attached to that assistance. It was impossible for me within the limited time that I could give to the investigation to gather together all the data requisite for an indisputable inference, and after I had left the town Dr. Robinson undertook and ably carried out the collection of such additional facts as appeared to be necessary.

The township of Armley is situated at the extreme west of the town of Leeds; it lies upon the south side of the River Aire, and chiefly upon the northern slope of a hill with a tolerably steep descent to the river.

Originally a suburban village of little importance, it has of late years been greatly extended by the erection of new houses in streets and blocks chiefly towards and at the summit of the hill and on its southern slope. There are some few villa residences in the outskirts, but the greater number of the newer houses are, like the majority of those in the older part of the village, of the cottage class.

Immediately beneath the surface-mould the soil, to a great depth, consists of a rocky shale which is loose in structure and readily permits the permeation of water.

The drainage throughout the township is very defective. No sewers have been provided anywhere except in some of the new roads now in course of construction. In the older part of the village of Armley there are some square drains, very imperfectly constructed of small slabs of stone. They are scarcely adapted even for carrying off the surface water from the roads, but are used, nevertheless, for the reception also, by means of open and untrapped gratings, of the domestic sewage of the village. When I was in the village the emanations from some of these drain gullies were intolerably offensive. In some of the newer parts of Armley pipe drains have been laid in, but even in some of these newer parts the drains are constructed as they are in the older parts, and the inlets are simply untrapped "dish-stones" which are commonly placed just outside the doors of the houses. Drain inlets within houses also, such as those at sink stones, are not by any means invariably trapped. In many parts the cellars are wet, and in times of heavy rain, in consequence of the small calibre and choking of drains, they become flooded.

Very few houses, even of the better class, are provided with water-closets. Large privy cesspools are the rule throughout the place; no

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public arrangements are made for their cleansing, and everywhere they were found exceedingly offensive. Taking into consideration the nature of the soil into which these cesspools are dug, and the loose construction of the drains in the village, the earth upon which the dwellings stand must be greatly polluted with soakage from both.

The water supply of Armley is from the Bramley reservoir of the waterworks of the corporation of Leeds, and is given by pipe and tap to the houses individually. I heard no complaint of the quantity furnished, but in some parts complaints were made by householders that the water had a fishy taste and odour in the hot weather. But these complaints were by no means universal. The analysis, by Dr. Dupré, of a sample of the water, which I took directly from the Bramley reservoir, gave satisfactory results. The details of his analysis are given in the Appendix to this Report.

Dr. Robinson tells me that Armley is one of those parts of the borough which is scarcely ever absolutely free from enteric fever, cases of which, although most abundant in the older and more low-lying parts of the village, have nevertheless occurred frequently in the newer parts also. It is his practice to inquire into the circumstances under which every fatal case of this disease has occurred, and he attributes the endemic persistence of enteric fever in Armley to the absence of proper drainage and to the excrement nuisances which abound there, and apparently with good reason. I have rarely seen anything better calculated to promote the spread of enteric fever than some of the privy arrangements in this place.

Still, taking as indices the Death Register and the Medical Relief Book of the Union Medical Officer, with such lists of cases of the disease as I could obtain from private medical practitioners, there does not appear to have occurred in Armley any great number of cases of enteric fever during the present year before the month of July; and then an outbreak occurred there unprecedented in extent in the experience of resident practitioners, and of the Medical Officer of Health. It was this outbreak which it became my duty to investigate.

Up to the end of April this year only two deaths from enteric fever had occurred in Armley, and by inquiry among the medical men practising in the township, I can only ascertain two other cases, which happened in April. It is probable, however, that there were others, but they were not so numerous as to attract any particular attention. On the 17th May two cases came under the observation of Mr. Coleman. One of them was that of a dairyman in Hall Lane, Armley, who, after consulting Mr. Coleman for some days at his surgery, and having kept at work as long as he could, first took to bed on that day. There is reason to believe that this man got his fever at a neighbouring town.* The other case was that of a man aged 22, residing in a house at Cricket Field, on the southern slope of the hill. It was fatal on May 24. Four or five weeks now elapsed before another case was observed, and then a man, aged 37, who worked at some ale vaults in Leeds, but resided in one of a block of four back-to-back houses, known as Oakes' houses, not far from the dairyman's dwelling, was attacked with enteric fever. He first came under observation on June 20, and he died from the fever on July 29. Before he died some of his family had been similarly attacked, the first of them about July 20, and after his death other cases happened among the children—the last case on August 27. Altogether five cases of enteric fever occurred in this house. From June 20 ten

* He had been in company with another person, who, it is believed, was taken ill with a similar fever about the same time.

days now passed without the known occurrence of any fresh case, and then came a sudden outburst. During the week which commenced on Sunday, June 30, and ended on July 6, cases of enteric fever came under observation in no fewer than 12 houses in Armley; in the next week, ending July 13, eleven fresh houses were invaded by it; in the next week, ending July 20, ten more houses, and in the week ending July 27, sixteen more. In the following week the number of fresh invasions suddenly fell to two; and from the first week in August until the end of the first week in September, a period of five weeks, there were altogether only fourteen fresh houses invaded by the fever. The total number of houses invaded during the above-mentioned seventeen weeks was sixty-eight; the total number of cases of fever which I have been able to ascertain was 107, of which eleven were fatal. These 107 cases were not scattered equally over all parts of the township, but were located within a limited space, which there was no difficulty in defining upon a map, and which is defined upon the plan which accompanies the office copy of this Report. The line defining the infected part of Armley includes a portion of the older, lower, and more crowded part of Armley, but chiefly that part in which the houses are comparatively new, and are built in airy situations upon the rise of the hill and upon its summit. Nor were the invasions of the fever confined to the cottages of the labouring class of the population; for although the greater number of the cases were met with in such cottages (as might have been expected considering their numerical preponderance), yet the fever did not spare the occupants of some of the least crowded together of the residences in Armley. The vicar of the parish had a severe attack, and one or more members of several families sufficiently well off to keep domestic servants also suffered.

The following Table has been constructed to show the progress and subsidence of the epidemic week by week, and, during the four weeks of its principal prevalence, the number of cases coming under observation, and of fresh houses invaded, day by day:—

1872. Week ending—		Daily. New Cases coming under Observation.	Daily. Houses newly invaded.	New Cases coming under Observation each week.	Houses newly invaded each week.
May 18				2 (1 fatal)	2
„ 25				—	—
June 1				—	—
„ 8				—	—
„ 15				—	—
„ 22				1 (fatal)	1
„ 29				1	—
July 6	June 30	1	1	14 (3 fatal)	12
	July 1	4	4		
	„ 3	1	1		
	„ 4	3	2		
	„ 5	1	1		
	„ 6	4	3		

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		Daily. New Cases coming under Observation.	Daily. Houses newly invaded.	New Cases coming under Observation. each week.	Houses newly invaded each week.
July 13	July 7	6	4	22 (2 fatal)	11
	„ 8	1	1		
	„ 9	3	—		
	„ 10	3	1		
	„ 11	3	2		
	„ 12	3	1		
	„ 13	3	2		
July 20	„ 14	2	—	19 (2 fatal)	10
	„ 15	7	4		
	„ 17	5	4		
	„ 18	1	—		
	„ 19	1	1		
	„ 20	3	1		
July 27	„ 21	3	2	24 (2 fatal)	16
	„ 22	4	1		
	„ 24	3	3		
	„ 25	6	4		
	„ 26	3	3		
	„ 27	5	3		
Aug. 3				5	2
„ 10				5	5
„ 17				2	2
„ 24				4	3
„ 31					1
Sept. 7				1	1
Invasions and attacks, the dates of which are not ascertained				5	2
Total				107	68

Thus the epidemic commenced suddenly, and almost as suddenly abated. Another remarkable feature in it was that, out of the twelve houses invaded in the first week of the epidemic, ending July 6, there were only two in which a solitary case occurred. In each of the remaining ten houses from two to six cases happened in succession. Again, in the second week of the epidemic, out of eleven houses newly invaded there were but three in which solitary cases of the disease were observed. From the third week of the epidemic onwards, however, the very reverse of this was noticed. Out of ten houses newly invaded in the third week, multiple cases in a house were only observed in two, while, in the fourth week, solitary cases only occurred in each of the sixteen invaded. All subsequent new invasions of houses were represented by solitary cases of fever, except in two instances. Whatever the explanation of the cause of the epidemic may be, the true cause can only be one which shall suffice to account satisfactorily for the facts just mentioned, viz., the suddenness of the outburst, the suddenness of the arrest of the epidemic, and the fact that multiple cases in a house were almost entirely confined to houses invaded during the first fortnight.

Of the 107 cases, 55 were males, 52 were females.

The attacks were met with in persons of all ages up to 65 years, and were distributed as shown in the following Table of 53 males and 52 females, whose ages are known :—

—	Males.			Females.			Both Sexes.		
	Under 5 Years.	5-14 Years.	15 Years and upwards.	Under 5 Years.	5-14 Years.	15 Years and upwards.	Under 5 Years.	5-14 Years.	15 Years and upwards.
Week ending—									
May 18th	—	—	2	—	—	—	—	—	2
June 22nd	—	—	1	—	—	—	—	—	1
„ 29th	—	1	—	—	—	—	—	1	—
July 6th	—	1	5	1	2	5	1	3	10
„ 13th	1	3	8	1	1	8	2	4	16
„ 20th	2	3	4	—	3	7	2	6	11
„ 27th	1	7	4	1	5	6	2	12	10
Subsequently	—	4	4	3	4	3	3	8	7
Date of attack unknown.	—	1	1	—	1	1	—	2	2
	4	20	29	6	16	30	10	36	59

In the above Table the comparatively late period in the epidemic at which most of the children were attacked is worthy of observation. Whatever the cause of the outbreak may have been, the older persons, on the whole, were attacked earlier than the younger, who either resisted more strongly the operation of the cause, or exhibited a longer period of incubation. This fact also comes out on comparing the mean ages of those attacked week by week. Thus:—

The mean age of 14 persons attacked in the week ending July 6, was $21\frac{1}{14}$ years.
„ 22 „ „ July 13, „ $20\frac{14}{22}$ „
„ 18 „ „ July 20, „ $18\frac{17}{18}$ „
„ 23 „ „ July 27, „ $15\frac{12}{23}$ „
„ 18 „ in subsequent weeks „ $14\frac{13}{18}$ „

Of the medical men practising in Armley, only one, namely, Mr. Coleman, the Union Medical Officer of the district, formed any decided opinion as to the origin and cause of the spread of the fever. It has been mentioned above that one of the two cases of enteric fever, which he was called upon to treat in the month of May, occurred in the person of a dairyman; and he observed that all the families attacked with the fever at the commencement of the outbreak dealt with this dairyman for milk. Naturally enough, the coincidence struck him as remarkable, and he mentioned it to Dr. Allbutt, of Leeds, who then brought to his notice for the first time the observations which I had made during a similar outbreak in Islington in the summer of 1870. At the date of the commencement of the present inquiry, Mr. Coleman alone held the opinion strongly that the fever had been spread by the milk proceeding from the infected premises of the dairyman. Dr. Robinson, although quite aware of the possibility of Mr. Coleman's surmise being correct, was little disposed to accept it, mainly on the ground that other explanations more probable had not been excluded, but, secondarily, on the ground of his experience of enteric fever on former occasions, both in Armley and in other parts of the borough. He was much more inclined to attribute the origin of the fever to the wretched condition of the drainage of the place, and its spread to personal communication with infected houses and persons, and to the use of privies infected with the dejections of the sick. During the heavy rainfall that preceded the outbreak, sewer air had been forced back into the houses, and sewage had bubbled up, he says, through the gully openings, and had penetrated into houses, and flooded cellars and yards in many parts of Armley: these conditions appeared to him to have been instrumental in promoting the outbreak. Before the inquiry was completed, however, some very curious facts.

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which had been established served to modify his views upon the subject.

On obtaining a full list of the cases of fever that had occurred, and on arranging the invasions of the several families attacked in chronological order, the *primâ facie* case presented to me by Mr. Coleman was considerably strengthened. Every family attacked up to the end of the first week in July dealt with the dairyman who had been sick with the fever in May; so did every family, with the exception of one, invaded in the second week of July; so did every family invaded in the third week of July. After this there was less uniformity in the milk supply of the houses invaded. In the fourth week of July, out of sixteen families newly invaded, ten dealt with this dairyman, while the remaining six distributed their custom among other milk sellers. The remaining sixteen families invaded subsequently, or at dates not precisely ascertained (but certainly late in the epidemic), dealt for milk as follows; viz., seven with the dairyman in question, seven with three other milk sellers, while in respect of the two, the source of the milk supply was not discoverable.

Whether the spread of the fever was due to the use of milk from the suspected dairyman's premises or not, it was thus at least clear that the part of Armley in which his business was principally carried on coincided to some considerable extent with the locality of the fever, as defined by the line drawn upon the plan accompanying the office copy of this report. But, inasmuch as it was not known to what extent the dairyman in question supplied the houses within the district, it became necessary to institute a house-to-house inquiry. This was partly carried out by myself, and partly by Dr. Robinson and his Superintendent Inspector of Nuisances.

The number of dwellings within the boundary line above mentioned was found to be 449, and they were occupied, with few exceptions, by separate families. Assuming that on an average there were five persons in each house, the population of the district would be about 2,245. It appears then that about 15 per cent. of the houses were invaded by the fever, and nearly 4·8 per cent. of the population were attacked by it. Of the 68 houses invaded, 51, including that of the milk seller himself, were supplied with milk by the dairyman in question; 13 were supplied by various other milk sellers whose names were known; one had no milk from anybody, and the source of milk supply to three was doubtful or unknown. It might have turned out after all that the proportion of invaded houses supplied by the suspected dairyman was no greater than the proportion of all the houses which he supplied with milk in the district. But inquiry showed that, although he actually supplied a very large number of houses within the defined district, he did not supply anything like 51-68ths of them. As a list of customers could not be obtained from the dairyman, it became necessary to ascertain the milk supply during the epidemic period by special inquiry at each house. The result of the inquiry was that, of the 449 houses within the defined district, 132 were supplied by the dairyman who had been ill, and the 317 remaining houses are accounted for as follows, viz., 37 never took in any milk at all; in respect of three the milk supply was doubtful; and 277 families occupying the remaining houses distributed their custom among 18 different milk sellers, of whom one supplied 80 families; one, 49; one, 45; two, 37 families each; one, 25; and one, 11 families.

We have arrived therefore at this, that altogether 37·8 per cent. of the families this single dairyman supplied with milk, after he himself had been attacked with enteric fever, were invaded by the same disease, while only about 5·3 per cent. of the families supplied by 18 other

milk sellers, or not taking milk at all, suffered from the fever. Of course the question must arise how was it, if the milk supply from the one infected source was the cause of the outbreak and of its spread, that 17 families not thus supplied suffered at all? And this question must be answered. The key to its solution lies in the observation that nearly all these 17 invasions occurred in the fourth week of the outbreak, and in subsequent weeks. During the first three weeks of July only one family not supplied from the infected dairy was attacked. Hence it is probable that the other 16 family invasions were instances of extension of the fever through the medium of privies, sewers, drains, &c., in places where the specific discharges of some of the earlier cases had been deposited. It was scarcely to have been expected that, even on the cause which occasioned the earlier cases ceasing to operate, the fever would fail to spread for a time in a place so imperfectly drained and cleansed from excrement, and with a soil so permeable as that of Armley. And in most of the 17 instances referred to, if not in all of them, exposure to the operation of virus conveyed by one of these media could be traced.

But while some of the later invasions and attacks of fever may be accounted for in this manner, it was impossible thus to account for the earlier cases, inasmuch as, up to the period of my visit to Armley in the middle of August, the evidence of any earlier spread of the disease in this manner was very slight. I have in my notes a record of many groups and blocks of houses which I made the subject of special personal investigation, taking them hap-hazard, each group or block using one common privy. In all of them, those families only had been invaded who obtained milk from the suspected source; the disease having up to that time been limited to such families, and having spared those who obtained milk from a different source, although using the same privy with the families invaded. Still, as I have said, at a later period in the outbreak there was more distinct evidence that the disease had begun to spread through the medium of infected drains, privies, and soil.

The manner in which the fever picked out the customers of the dairyman in various rows and blocks of houses, sparing other families, was indeed remarkable. Beside the instances referred to in the last paragraph many others might be adduced. Two may suffice in illustration. In Hall Lane, close to the dairy, is a row of 10 houses occupied by well-to-do families. Eight of these families obtained milk from the dairyman in question, and of these five were invaded by the fever. The other two families obtained milk from other sources, and neither of these families suffered. The other instance is the most remarkable of all. There is near Armley Gaol, and at a distance of half a mile from the dairyman's premises, a row of 12 new houses (Hawthorn Place), in one of which a lady aged 53, who very rarely left the house, died from the fever, with which she was attacked early in July. Inquiry was made by Dr. Robinson from house to house, and it was ascertained that no one else in the row had similarly suffered. It was also ascertained that this family alone dealt regularly with the dairyman in question, and as it was beyond the district he supplied, a son of the lady who died fetched a quart of milk every afternoon, of which she took a considerable portion every night for her supper. There was one other house in the row where the milk from this source is said to have been occasionally taken in, but no fever occurred in it.

In the course of the investigation I took some trouble to discover the quantity of milk consumed by the individuals attacked, and in a considerable proportion of cases I obtained the information sought. Thus I have notes of 19 cases in which it was especially mentioned that

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the suspected dairyman's milk was very freely used as an article of diet, commonly at supper, either cold or boiled. All but four of these individuals applied for medical aid in the course of the first fortnight of the outbreak. On the other hand, I have notes of 24 cases in which it is especially mentioned that the individuals took very little milk, and of these 17 sought for medical aid in the course of the third and fourth weeks of the outbreak, and only three in the first and five in the second week. So that it appears that the largest consumers of the suspected milk were among the earliest, and the smallest consumers among the latest attacked.

It may now be considered established that the outbreak of enteric fever which suddenly occurred in the first week of July in Armley was caused by the distribution through a part of the township of milk from a particular dairy where the dairyman himself was lying ill with enteric fever, and where subsequently two of his children also suffered from the same disease.

As to the mechanism of the distribution of the fever from the dairyman's premises, there arises at the outset a question which it is desirable to answer, but to which, in the nature of things, a direct answer can hardly be expected. Was it water added to the milk that produced the enteric fever among families supplied from the dairy? No one knows anything of enteric fever being propagated by cow's milk, *per se*, while there is very ample knowledge about the spread of such fever by means of water. The following considerations lead one to believe that it really was not through milk, but through water added to milk, that the customers of the Hall Lane dairy got their infection of enteric fever. Houses occupied by families supplied from this dairy were invaded freshly, one after another, almost every day up to July 27th: on that day three houses so occupied came freshly under medical notice; and from that day the epidemic, as such, was at an end. In the whole of the next week only one family dealing with the Hall Lane dairy, applied newly for medical aid.* This sudden cessation of the fever epidemic among this section of the community on July 27th, means that the cause of the epidemic had ceased for them a fortnight or more previously, since in enteric fever there are commonly 11 days of incubation and several other days before medical advice for its symptoms is sought. July 10th would therefore be about the time when the cause of the epidemic among customers of the dairy suddenly ceased to operate. Now, on July 10th, Dr. Robinson had the handle of the pump at the Hall Lane Dairy chained up, and thenceforth it was kept chained. There was coincidence therefore between the cessation of the fever and the cessation of the opportunity that the dairy had to supply a particular water; while there was no suggestion that the cows or their milk had undergone any change.

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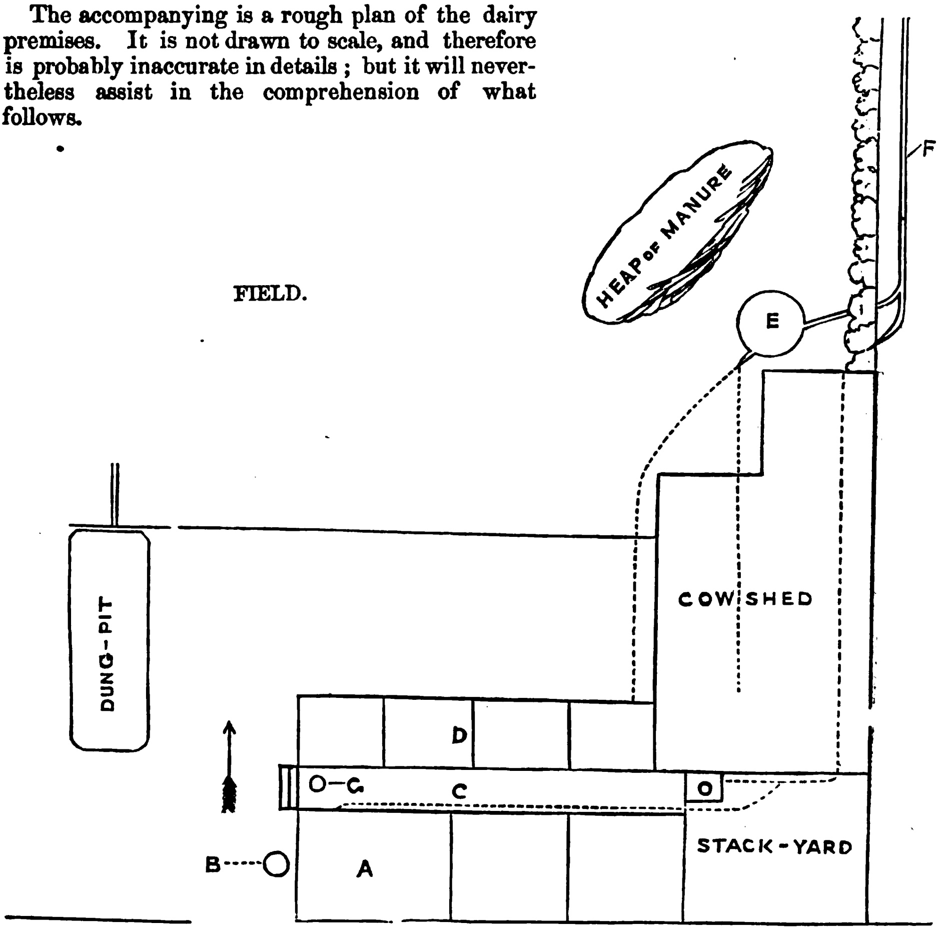
* In the week ending August 3, only one family was invaded. The attack occurred in the person of a little girl, for whom medical aid was sought on July 28. We know how obscurely this fever may begin in a child, and the mother of this girl, from what I learnt about her, was quite the sort of person to pooh-pooh the child's illness until it became really serious, so that it may well be believed that she was ill long before the 28th. The next case came first under observation on August 4, and it occurred in the person of a young man who resided in the lowest house of a row of cottages, in several of which fever had occurred, and the common drain from which passed his house where there was an untrapped opening opposite the door. He is very likely to have received the virus from this source, and not from the milk he used. Between this date and September 1, altogether 11 houses were invaded by fever, but out of all of them only four were occupied by families using the milk from the dairy in question—a proportion no larger than might be not unfairly accounted for by the proportion of families in the district supplied from it with milk.

It is, as I have said, not to be expected that evidence, other than circumstantial evidence, should be obtainable respecting the admixture of water with the milk. If it occurred as an adulteration (such as dairymen are pretty generally accused of practising) the fact would be concealed; if accidentally, the fact would have escaped notice altogether, or would be forgotten.

No direct evidence on the point was forthcoming beyond certain admissions about the use of water from the well of the premises in cleaning out the milk cans. I propose, therefore, to give the evidence that could be obtained, relating to the position and construction of the well, the character of its contents as observed by myself and as determined by analysis, the opportunity that the well had to become specifically infected, and the coincidence in point of time between such infection and the cause of the fever among the milkman's customers. This evidence, joined with the facts above given as to the cessation of the epidemic when the well-water was disused, will leave, I think, no doubt about the part that was played by the dairyman's well in the production of the fever.

The accompanying is a rough plan of the dairy premises. It is not drawn to scale, and therefore is probably inaccurate in details; but it will nevertheless assist in the comprehension of what follows.



A. Dairyman's house.
B. Well, with pump.
C. Paved way to back doors of houses.
D. Row of pigsties.
E. Open cesspool.
F. Open drain.
G. Urine tub.
----- Course of drains.

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The dairyman's house is the first in a row of three cottages which have doors opening in front upon the lane, and at the rear upon a paved passage which is artificially raised to the level of the roadway in front, and is reached by one or two steps. The land slopes so much downwards, in the direction of the arrow, at the rear, that the roofs of the row of pigsties marked D on the plan are at the level of the paved way. In most other respects the plan explains itself. The dung-pit is situated about five yards from the well. It is very large, and dug about three feet into the earth and rocky shale. At the time of my visit it was full of filth and manure, and was partly drained by a channel cut in the earth into a field in the rear. The paved way at the rear of the cottages is provided with a covered channel for slops, but the pipe intended to convey the slops through the wall at the end of the passage to the drain in the stack yard at a lower level was, at the time of my visit, choked up. The privy for the three cottages at the end of the paved way was full of excrement, from which some liquid matter alone drained imperfectly away by means of a pipe drain at the rear. There was an oozing of liquid matter also on to the surface of the stack yard behind the privy. Altogether the drainage arrangements were found to be exceedingly bad. The cesspool E receives the drainage from the cow shed, pigsties, and privy, and all the household slops, except the urine, which is collected in a sunken tub at the entrance to the paved way, and only a few yards from the well.

The well was situated at the side of the dairyman's cottage, and was covered with a slab of stone. On removing the cover I found that the well was sunk in the porous shale of the district to a depth altogether of 36 feet; the depth of water was 12 feet, and the distance from the surface of the water to the top of the well was 24 feet. From the top of the well to a depth of 22 feet the sides were formed of bricks loosely laid upon one another without cement. Below this depth the surface of the shale was exposed. For the first four feet from the top of the well the outside of the brickwork was puddled with clay, but not lower. All the way down below the place where the puddling ceased there was observed an oozing of black matter from between the bricks, and below the spot where the brickwork ceased the oozing was considerable, as shown by the staining of the stony portions of the soil, and by a black stain 12 inches wide on the side next the dung-pit reaching to the water two feet lower down. There was a deposit of mud and filth at the bottom of the well which gave off abundant bubbles of gas on being disturbed.

Previous to exploring the dairyman's well a sample of the water was taken for analysis. The details of the analysis are given in the Appendix to this Report. Briefly, I may state here that it gave evidence of considerable sewage contamination, and that although nearly all the organic matter in the specimen collected on August 22nd had become oxidised, the water contained much chlorine and an excessive amount of nitric acid which could only have arrived at it in the manner mentioned. The water then was polluted with sewage matters, evidently in great measure from the dung-pit, but partly also almost inevitably by soakage through the soil from the privy or from defective drains and perhaps also from the decaying urine-tub which had evidently been many years in use.

That the water had thus an excellent opportunity of being polluted with human excrement can scarcely be disputed. Even supposing that no slops containing such excrement had been at any time thrown into the dung-pit, an event which the slovenly habits of the family render by no means improbable, there were other chances for these slops or the soakage from the privy getting into the water.

I propose next to show that the well probably became from a parti-

cular time specifically polluted with the matter of enteric fever, and this was exactly the time at which the cause of fever among the milkman's customers began to operate.* Among these people the earliest cases came under observation about the 1st of July. Probably these persons, as well as most of the individuals on my list who were attacked, had been ill for a period of a few days to a week before they sent for their medical attendant; and then to this interval must be added 10 or 11 days as the period of incubation before we can fix upon a date on which the persons earliest attacked received the virus into their stomachs. This date then will be thrown back to a time somewhere between the 14th and the 21st June. Mr. Miall, of the Philosophical Hall at Leeds, has kindly furnished me, through Dr. Robinson, with a copy of his rainfall register, week by week, prior to and during the outbreak. And I find from this that the weekly rainfall during the months of May, June, and July was as follows:—

Week ending—	Rainfall in inches.	Week ending—	Rainfall in inches.
May 4	0·539	June 22	1·065
„ 11	0·410	„ 29	1·556
„ 18	0·811	July 6	0·240
„ 25	—	„ 13	3·190
June 1	0 036	„ 20	1·170
„ 8	1·400	„ 27	0·800
„ 15	0·539		

The dairyman was taken ill in May. During the whole of May the rainfall was moderate, and no rain at all fell in the first week after he took to his bed. In the second week very little fell, but in the third week nearly an inch and a half fell, and in the fourth week more than half an inch more. It was at this time then that, in all probability, the virus began to be washed from the dung-pit or polluted soil towards the well, and it might take a few days more for it to arrive at the water. That the process of percolation was ordinarily a slow one appears to be shown by the oxidised condition in which the organic matters mostly reached it. But we must believe, taking the period of this rainfall into consideration, that foul matters, at the time having specific infectious qualities, were being passed into the well with particular rapidity during the second week of June, that is to say, just before the time that the earliest cases may be presumed to have received the virus. In the two following weeks a great deal of rain fell, which would naturally continue to wash the virus out of the soil into the water.

I stated in an earlier part of this Report that, whatever the true explanation may be, it should be such as should account for the suddenness of the commencement and of the cessation of the epidemic outbreak, and that it should also be capable of accounting for the fact that multiple cases were almost entirely confined to houses invaded early in the epidemic. The first requirement has been fulfilled; and I submit that the explanation given above also fulfils the second: for had it been true that the second, third, or subsequent attack in each family had been due to any other cause than the same cause as produced the first case in the family, viz., the use of the same polluted milk; if they had

* This well was in ordinary use in the dairyman's house and in two adjoining cottages. Members of the dairyman's family, and the nurse who attended on him, were attacked with the fever after his own illness. In one of the adjoining cottages there were, about the same time, two cases of fever. At this time the second cottage escaped, the only people who took their meals there being two old persons probably insusceptible of the disease. About a month, however, after the pump was chained, a girl who slept at this second cottage became ill of fever, having probably got it elsewhere.

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been due, for instance, to accidental causes connected with the pre-existence of a first case in the house; we should naturally have expected that, in due time, the families invaded by the epidemic at the later period would have presented multiple attacks in the same way as those attacked earlier. But such was not the case.

It is not necessary that I should point the moral of this history, or deduce from it the warning that it must convey to any thoughtful mind. The Adulteration of Food Act of last Session enables local authorities to deal with persons who add water to milk; but if a dairyman's own drinking water is permitted by local authorities to be a fluid little better than sewage, is it not rather a reflection on those authorities than an aggravation of his commercial fraud, that he, only meaning to dilute his milk, ignorantly supplies infection to his customers?

But I must say something, before I conclude, about the local authority in Armley, which is the Corporation of the borough of Leeds. The unwholesome condition of the outlying township of Armley should early receive the serious consideration of the Leeds Corporation, especially in respect of sewerage and house drainage, and the frequent removal and safe disposal of excrement. It is not necessary for me to dwell in detail upon either of these subjects, inasmuch as they were fully brought under the notice of the Corporation as long ago as July 1871, by Mr. J. N. Radcliffe, in his report on the sanitary state of Leeds. A year and a half has elapsed since that report was presented, and nothing has been as yet done to carry his recommendation into effect in this suburb; notwithstanding that it is one of those parts of the borough which the Medical Officer of Health of the Corporation has mentioned in his report for 1871, as among the localities in which fever principally prevailed during that year, and which he mentioned to me as one from which enteric fever is rarely absent.

Note.

The following is the result of the chemical analysis made by Dr. Dupré of the two samples of water mentioned in this Report, both taken August 22, 1872:—

1.—*The Water of the Bramley Reservoir.*

The water is almost perfectly clear, leaving only a minute trace of deposit; it is soft, becomes extremely soft by boiling, and contains only traces of nitric acid and chlorine. But little organic nitrogen and only minute traces of ammonia are present; the water is in these respects extremely pure. It contains, however, an appreciable amount of some vegetable (peaty) matter, which gives it a decided colour, and absorbs a comparatively large amount of oxygen. Moreover the dry residue when ignited shows much blackening.

The following are the details of the analysis:—

Appearance - - -	Clear.
Colour - - - -	Pale brown yellow.
Deposit - - - -	Fine granular.
Taste - - - -	Slightly mouldy.
Smell - - - -	Ditto.
Nitrous acid - - -	None.
Phosphoric acid - - -	Extremely minute trace.
Hardness, on Clark's scale - -	9·5 deg.
,, after boiling - -	3·5 deg.

	Grains per gallon.
Oxygen absorbed from permanganate - -	0·101
Total solids - - - - -	9·240
Consisting of—	
Volatile matters - - - -	3·199
Fixed salts - - - - -	6·041
Chlorine - - - - -	0·490
Nitric acid ($N_2 O_5$) - - - -	0·205
Nitrogen in ammonia - - - -	0·0017
Organic nitrogen - - - -	0·0105

2.—*The Water from the Well on the Premises of the Dairyman referred to in the Report.*

The water is turbid and extremely hard, even after boiling. It contains much chlorine and an excessive amount of nitric acid, both probably derived from some considerable sewage contamination. Although, at present, nearly all organic matter has become oxidised, the water is nevertheless a very bad one.

The analytical details are given in the following table:—

Appearance - - -	Somewhat turbid.
Colour - - - -	Yellowish.
Deposit - - - -	Brown, flocculent.
Taste - - - -	Very slightly mouldy.
Smell - - - -	Inodorous.
Nitrous acid - - -	Minute trace.
Phosphoric acid - - -	Trace.
Hardness, on Clark's scale - -	54 deg.
„ after boiling - -	52·5 deg.

	Grains per gallon.
Oxygen absorbed from permanganate - -	0·042
Total solids - - - - -	102·060
Consisting of—	
Volatile matters - - - -	19·890
Fixed salts - - - - -	82·170
Chlorine - - - - - -	9·600
Nitric acid ($N_2 O_5$) - - - -	15·422
Nitrogen in ammonia - - - -	0·0042
Organic nitrogen - - - -	0·0084

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APP. No. 5.

Enteric Fever at Moseley and Balsall Heath, by Dr. Ballard.

REPORT by DR. BALLARD, upon an OUTBREAK of ENTERIC FEVER at MOSELEY and BALSALL HEATH, near BIRMINGHAM.

On January 2nd I received instructions to inquire into a serious outbreak of enteric fever which had suddenly occurred at Moseley and Balsall Heath, suburbs of Birmingham. These places are situated on the summit and sides of a ridge of hills running in a southerly direction from Birmingham. The causes to which the fever had been popularly attributed were the absence of proper drainage and the pollution of the wells with sewage matters.

I found on inquiring that the porous soil on which these places are situated had, in fact, become extensively polluted by soakage into it from dumb wells or of matters from time to time pumped out of them, as also by soakage from badly constructed drains and ash-pit privies, and that there was abundant evidence that the wells which had supplied water for domestic use to the greater part of the population were also much polluted with sewage or excremental matters. But I found also that these conditions, prevailing widely throughout Moseley and Balsall Heath, failed to explain the peculiar distribution of the fever, or to account for the invasion of certain families, while neighbouring families in apparently similar circumstances had entirely escaped. Moreover I ascertained as fact, and was unable merely by reference to existent local conditions to explain how it had arisen, the fever had spared the whole class of the population which when ill is in the habit of seeking parochial medical relief, while it had attacked families residing in the best villa residences in Moseley, and many families residing in expensive houses in which the local conditions usually regarded as promotive of enteric fever were less obviously present than among the poorer classes.

The private medical practitioners who were in attendance upon cases of fever kindly gave me their assistance in the inquiry which I instituted, and permitted me to see all the persons who were suffering at the time of my visit, and in all I recognised the fever as enteric. Some of the cases were very severe and very typical, but others, as is usual in similar outbreaks, were milder and less strongly marked. All, however, that I saw were sufficiently characterised to enable me to determine the nature of the disease.

Prior to the end of November there had been no unusual prevalence of enteric fever in Moseley and Balsall Heath, but in the course of the last few days of November and the first week of December (ending December 7) 20 families in these districts were invaded; in the week ending December 14th, 11 families; in the week ending December 21st, 12 more families; and in each of the two succeeding weeks, three families. One family was attacked, the precise period of invasion of which is not known. Thus 50 families (23 in Moseley and 27 in Balsall Heath) are known to have been invaded by enteric fever between about the 24th November and the 6th January. In these families 96 cases (51 in Moseley and 45 in Balsall Heath) occurred, of which 10 were fatal.

The following table shows the number of families invaded and the cases occurring week by week during this period.

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Successive Weeks of the Epidemic.	No. of Families invaded.	No of Fresh Cases.	Died.
Week ending November 30 - -	4	5	1
" December 7 - -	16	25	3
" " 14 - -	11	22	4
" " 21 - -	12	17	1
" " 28 - -	3	14	1
" January 4 - -	2	5	—
" " 11 - -	1	5	—
Date unknown - - -	1	3	—
Total - - - -	50	96	10

I have not been able to ascertain the invasion of any new families subsequently to January 11th. The number of cases in a family varied from one to seven, the largest number of attacks occurring in those families which were invaded the earliest, as shown in the following table:—

Cases as distributed among families attacked in successive weeks.

Weeks in which Families were attacked.	Total.		Families with Cases respectively as below.				
	Cases.	Families.	One Case.	Two Cases.	Three Cases.	Four Cases.	Five Cases and upwards.
1st week - - -	49	20	7	6	2	3	2
2nd week - - -	18	11	6	3	2	—	—
3rd week - - -	17	12	9	1	2	—	—
Later - - -	10	6	4	—	2	—	—

Of the 91 whose ages are known, there were 25 under five years of age, 36 between five and 14 years of age, and 30 at ages varying between 15 and 52 years. Of those over 15 years, 24 were females. Hence out of the whole number attacked (whose ages are known) it is noticeable that only six were males above 15 years of age (of whom only three were aged 20 and upwards) while all the rest of the sufferers were women and children.

Failing to find an explanation of the peculiarities of this outbreak in any peculiarities of local conditions under which the invaded families lived, other than those under which other families lived which were not invaded, and guided by the former experience of similar outbreaks, I turned my attention to the milk supply of the neighbourhood, and the result of my inquiries in this direction was as follows:—

Of the 50 families invaded, 31 obtained their supply of milk from a milk-seller in Balsall Heath, whom I will call No. 1; four obtained their milk from a milk-seller whose premises adjoin those of No. 1, one house only intervening, whom I will call No. 2; 10 obtained their milk from a milk-seller whom I will call No. 3, who, although keeping one or two cows himself, purchased a portion of the milk he supplied to his customers from No. 1; and two obtained their milk from a fourth milk-

seller, whom I will call No. 4, and who purchased part of his milk from No. 2. Thus out of the 50 families invaded, 47 obtained their milk supply either wholly or in part, and either directly or indirectly, from two milk-sellers, Nos. 1 and 2, whose dairies were situated close together in a street in Balsall Heath. The remaining three families did not obtain their supply of milk from any of the above sources, and their fever cases must be otherwise accounted for. They were solitary cases. One occurred at Sparkbrook, at the outskirts of the Balsall Heath district, in a place notorious for the endemicity of enteric fever, and the other brought the disease with her into Balsall Heath from a distant part of Birmingham, while the third case had an origin which I was unable to trace.

There are a large number of other milk-sellers supplying families in Moseley and Balsall Heath, even in the same streets as the invaded houses, but no enteric fever occurred among their customers so far as I could learn, with the exception of the three solitary cases above referred to.

The connexion of the outbreak with the supply of milk to the 47 families being thus traced, the peculiarities of the outbreak become explicable. Thus it is obvious why women and children, who are milk-drinkers more commonly than are grown-up men, suffered so disproportionately to the latter, why certain houses were invaded while other closely adjoining houses similarly circumstanced as regards local conditions escaped, and why multiple cases occurred together or in quick succession in nearly half the families invaded.

Other facts not hitherto mentioned also become explicable, and add confirmation to the view adopted. One of the first persons attacked with the fever was a boy who assisted milkman No. 1 in his business. He was attacked about the same time as the first of the invaded families which No. 1 supplied. About three weeks later, the family of milkman No. 3, who obtained part of his milk from No. 1, was also invaded with the fever in the person of another boy, a son of the milkman. Both these boys drank abundantly of milk.

I think it clear that the milk supplied to the 47 families, and which gave them enteric fever, was infected with the virus or contagium of that disease. It remains to be shown how the milk acquired this infection, and for this purpose I must enter into some detail.

The accompanying plan (*see* p. 95) of the block of premises in which the dairies of milkmen Nos. 1 and 2 are situated in great measure explains itself.

It is to be remarked that the entry to the yard adjoining the dwelling A belonging to milkman No. 1 is closed by a door; but that the entry I to the joint-yard of the dwellings B and C is not so closed, but that at all times, both by night and by day, there is free access to it from the street. The pump E is used by the family of milkman No. 1 alone. The pump F is used jointly by the family occupying dwelling-house B, and by that of the milkman No. 2, occupying dwelling-house C.

Milkman No. 1 did not keep cows upon his premises, but purchased the milk which he supplied to his customers from a farmer in the country, a few miles beyond Moseley. The milk thus purchased was in part distributed to customers on the journey home, the remainder being for sale at the dairy in Balsall Heath. In consequence of a communication which was made to me by the surgeon who attended the boy who was taken ill at this milkman's house as mentioned above, and who subsequently died, I called upon the boy's mother, and she told me that on two occasions, once before his illness and once during his illness, he

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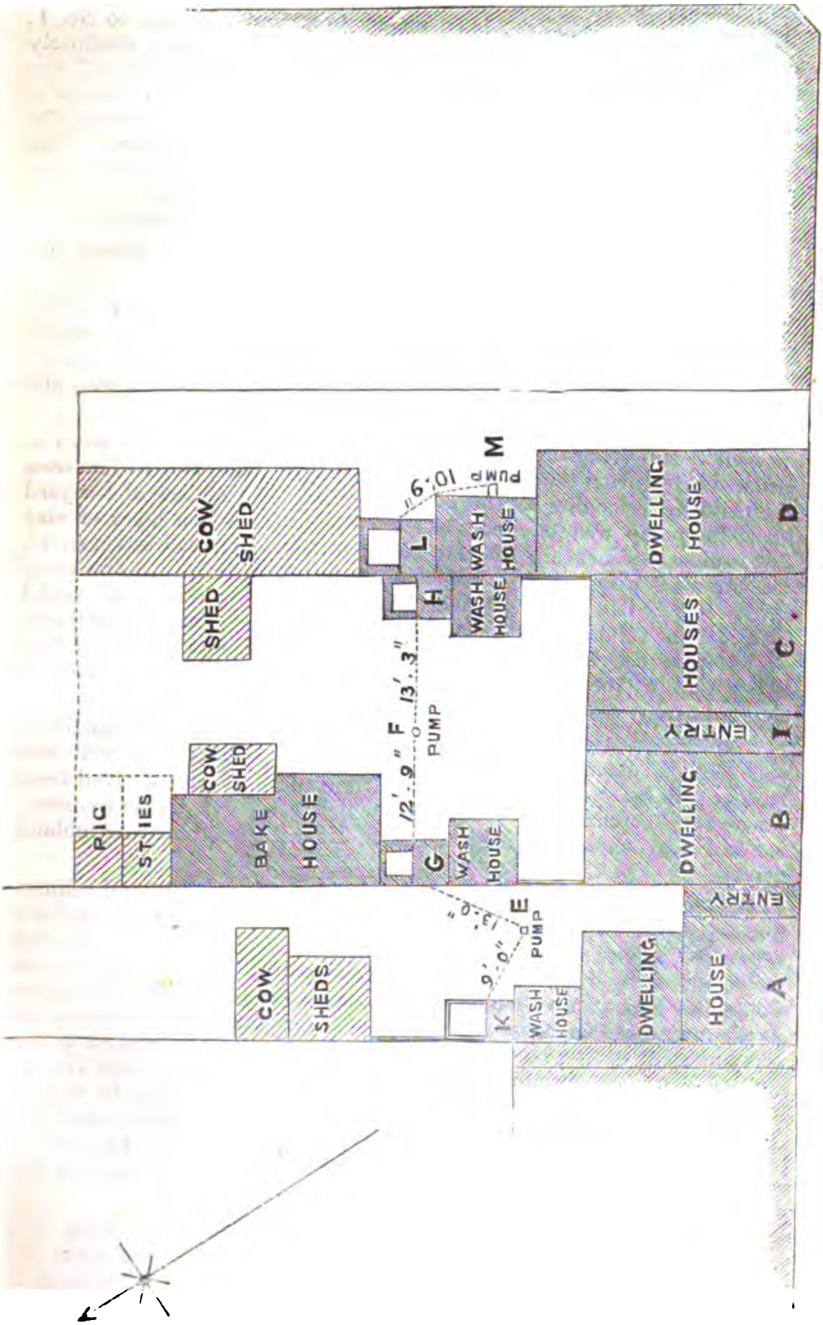
Enteric Fever at Moseley and Balsall Heath, by Dr. Ballard.



Scale 22 feet to 1 inch.

had informed her that water from the milkman's premises was added to the milk before its distribution. Milkman No. 2 also kept no cows at his premises, but purchased the milk he supplied from a farmer, and he also distributed the milk to his customers in a similar manner to No. 1. Milkman No. 2 made no profession to me of selling milk absolutely pure; and, although I have no positive evidence that the milk sold was watered, I think it not unlikely that he followed the ordinary custom of the trade in this particular. There had been no enteric fever on the premises of either of the farmers who supplied these two men. That the source of the infectious matter in the milk of No. 1 was independent of the farmer's premises is shown by the fact that this same farmer supplied from his premises two other milkmen, one at Acock's Green, and one at Aston, and that no enteric fever had appeared among the customers whom they supplied.

My attention was thus directed to the wells marked E and F on the plan. Both wells are situated within a few feet of pervious ashpit privies, are superficial, and are sunk in the porous earth which overlies the clay in this situation. Both wells were opened and examined, and samples of water from each were taken for analysis.

Well E supplying the water used by the family of milkman No. 1 is situated 9 feet from the ashpit privy K of his premises, and 13 feet from the privy G, belonging to the next house B. The surface of the yard about the pump was bricked; beneath the bricks was a layer of clay 1 foot deep, and beneath the clay there was an imperfect wooden cover. On the well being opened its sides were found to be constructed of bricks loosely laid together, and they were deeply stained all round inside. The total depth of the well was 12 feet, and there were 8 feet of water in the well; the surface of the water was, therefore, 4 feet below that of the yard. The statement was made that the water is cloudy in rainy seasons.

Chemical analysis, the details of which are given in the Appendix to this Report, demonstrates that the water (No. 1) of this well was largely polluted with elements which it could only have derived from sewage or excremental matters, and which, there can be no question, reached it by soakage through the earth from the neighbouring midden privies.

Well F, supplying the water used by the families occupying dwelling-house B, and by that of the milkman No. 2, was very similarly circumstanced. It was situated about 13 feet from the ashpit privy G, and about the same distance from the ashpit privy H, belonging to the milkman's house, on to which privy adjoined another privy, belonging to the next dwelling-house D. As might have been expected from the greater facilities for pollution from privies of similar construction to the former, the water showed on analysis (see Appendix, analysis No. 2) evidence of excremental pollution greater in amount than that in well E. It was similarly constructed to well E, but the water quite reached the cover. The total depth of the well was 16 feet 6 inches, the depth of the water 12 feet 10 inches, and the distance from the surface of the yard to that of the water 3 feet 8 inches.

The dwelling-house and dairy D, belonging to another milkman who kept cows, was also provided with a well and pump, marked upon the plan, situated very close to the combined privies of the dwellings C and D. As this milkman had no fever cases among his customers I did not think it necessary to examine the well or its contents, which, how-

ever, could scarcely fail to be as much polluted by ordinary excremental matters as his neighbours' wells.

Subsequently to November 30, if not a little earlier, the well of milkman No. 1 might have been infected by soakage from the privy K, which was used by the boy who had enteric fever at the milkman's house, but who, after having been ill about a fortnight there, and having during that time suffered from diarrhœa, went home and died of enteric fever on December 25. But observing that the earliest cases among the customers of both milkmen Nos. 1 and 2 occurred simultaneously, or nearly so, with this boy's attack, and allowing for the ordinary period of incubation of the fever, the cause of the illness among all these persons must have been in operation as early as about November 14, and the probability becomes very great that the infection of the boy and of the first attacked customers was derived from the same source.

I have stated above that there was nothing to indicate any injurious quality in the milk as it was originally supplied by the farmers; whereas, after reaching the milk-sellers, it was liable to be mixed with water from a manifestly dangerous source. The wells of both milk-sellers are so related to privy G that they might both have received excremental soakage from it, and both of them to nearly the same extent; and they might further have both of them received infection, if infectious matter had entered privy G. Further, I have stated that the milkman residing in dwelling-house D, whose well could not fail to have been greatly polluted with ordinary excremental matters, but which was much further removed from privy G, had no enteric fever among his customers. The inference to be drawn from all the foregoing considerations is,—1st. That the source of the infection of the milk of the two milk-sellers Nos. 1 and 2 was not on the premises of the two different farmers who supplied them. 2nd. That it was to be looked for on the premises of the milkmen themselves. 3rd. That the wells of both milkmen were probably polluted from the same source, namely, privy G, and the water of these wells being added to the milk, either intentionally or accidentally, was the medium of carrying infectious matter to their customers.

It only remains now to be shown that privy G had been itself infected prior to November 14 with the infectious matter of enteric fever. Such an event appears actually to have happened.

A man residing at the dwelling-house marked B on the plan, died there from what I believe was enteric fever on November 23. This man had diarrhœa from November 3, and was seized on the 17th with rigors, marking probably the commencement of the fever. His evacuations were thrown into the ashpit of the privy marked G on the plan. This case was regarded by the medical attendant as one of dysentery, but probably it was truly of the nature of enteric fever.*

* The history of this case as given me by the medical attendant was as follows:—The patient was an old man, aged 70, a master baker by trade, who resided in the same house with his wife, aged 65, and his daughter, aged 27. On Sunday, November 3, he visited his son in Birmingham, and after partaking of an ordinary dinner with him, had great pain in his bowels as he returned home. He had diarrhœa for several days, but as he frequently suffered in this way, he took no more notice of it than to use domestic remedies. He had some medicine at the surgery on the 8th. On the 11th he was visited and was found still to have diarrhœa, with pain in his bowels. The diarrhœa (though occasionally better) got worse, and he became

The etiology of the outbreak of enteric fever at Moseley and Balsall Heath may, in my opinion, be thus summed up:—

1. Two wells upon adjoining premises occupied by milk-sellers, became infected early in November with the infectious matter or virus of enteric fever through the soakage from a privy into them of excremental matters containing that matter of infection.

2. Through the medium of water drawn from these wells the milk supplied by these milk-sellers became infected, and many of their regular customers who drank the milk suffered from the disease.

3. The same infected milk having been sold to two other milk purveyors, some of the persons using the milk supplied by these milkmen also suffered in a similar manner.

4. There is no evidence that the disease spread in these districts in any other way than through the consumption of these infected milks.

Through the kindness of Mr. Ross Jordan of Moseley, and Mr. Turner of King's Heath, I have, however, had an opportunity of investigating a localized outbreak of enteric fever in Beoley Lane, about a mile out in the country beyond Moseley, which was, in fact, an offshoot of the Moseley outbreak. In this lane, and distant a quarter of a mile from any other dwellings, is a row of five cottages, occupied by labouring people and their families, and a few yards from the row an isolated cottage standing in some garden ground. Numbering the cottages in the direction of the slope of the land from above downwards, the first case of fever occurred at No. 2 on January 4 in the person of a boy aged 17 years. On this day the initiatory rigors and headache were observed, and his medical attendant was sent for on the 6th. It is said that he had rose spots, diarrhœa, and elevated temperature. His convalescence commenced on the 27th, and when I saw him on February 12 he was merely suffering from debility. This boy had not been from home except to his work at some rolling mills, nor had he taken any meals from home except at the mills. None of the workmen there had fever either previously or subsequently to his illness, nor had there been any enteric fever in the neighbourhood. No fresh case occurred in these cottages until January 20, when a girl aged 16, who had not been from home for a fortnight, was taken ill at No. 5. When I saw her on February 12 she was severely ill with enteric fever characteristically marked. On January 31 a child aged four years was taken ill at No. 4. She had not been from home for a long time previously, and was ill in bed with marked enteric fever when I saw her on February 12. Her mother states that another girl of the family, who looked weak and ill,

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feeble, and took to his bed. On the 17th he was seized with intense shivering and "dysenteric" diarrhœa, passing blood, with mucus, pus, and feculent matters of an intolerably offensive character, many times in the day. There was general abdominal tenderness and fulness, but chiefly on the left side. He was never hot, except when in violent pain; and his wife stated that there was, on the contrary, a tendency to coldness during the whole illness; but no thermometrical observations were made. No typhoid-spots were observed, although the abdomen was examined every day. The medical attendant says he believes he should have seen them had they been present, although he did not specially look for them. There was no marked delirium, and only a little wandering during the day or two before death. "The man died collapsed from exhaustion and loss of blood."

The case was an obscure one, but on reviewing the above history there is nothing to preclude the notion of its having been one of enteric fever, while the character of the evacuations, and the hæmorrhage sufficient in amount to occasion fatal exhaustion, throw the balance of probabilities in that direction.

had had a slight attack of a similar character. On February 1 a woman aged 47, who was a chronic invalid and never left the house, was attacked at No. 5, being thus the second case in this house, and she was in bed with the fever when I saw her on the 12th. On February 5 a girl aged nine years was attacked at No. 1, and on the 10th another girl aged six years. I saw these two children ill in bed on the 12th with enteric fever. Thus, out of the five cottages in the row, all had been invaded by February 12, with the exception of one which was occupied by three adult labouring men. No case of fever had occurred at the isolated cottage beyond No. 5, occupied by three females, aged respectively 55, 18, and 12 years.

It appears that the person occupying No. 1 is a laundress, and did all the washing for a family in Moseley, in which a fatal case of enteric fever had occurred. The only person in that family who had suffered was a servant, who was first seen by the medical attendant of the family on December 11, but who had been ill some days previously. I saw her with well-marked enteric fever on January 8, and she died from that disease on January 11. During the greater part of the time that this young woman was under medical care, the evacuations were all carefully disinfected with carbolic acid, and the soiled linen which she had used was, before being sent to the wash, soaked in a Condy's solution, and I have ascertained was so received by the laundress. But in the earlier stages of the illness, before she was seen by a medical man, and for a week subsequently, no disinfectant had been used. I have ascertained that, during the week before she was first seen by the medical man, she suffered much from diarrhœa, and that on Monday, December 9, linen soiled with her diarrhœal discharges and not disinfected was sent to the wash.*

The five cottages in Beoley Lane have in common, at the rear, a yard imperfectly paved with bricks, and along this yard, parallel with the cottages, runs a narrow channel, constructed of two rows of bricks meeting at an obtuse angle. This channel, on reaching the third house, turns off to a gully 3 feet from the well, and provided below with a receiver constructed of bricks loosely laid and puddled round the sides with clay. In passing to the gully the channel crossed the top of the well, the imperfect wooden cover of which was found on examination to lie only 1½ inches below the channel, the intervening space being filled with clay and ashes through which water might percolate. The brickwork over the rest of the well was loose, and permitted water to sink through between the bricks. From the receiver beneath the gully a badly constructed small brick drain carried off the overflow. The well was sunk in gravel and loosely bricked round; the brickwork within showed no marks of staining by percolation. The total depth of the well was 10 feet 4 inches from the surface of the yard; the surface of the water was 4 feet 10 inches below that of the ground, and the depth of the water was 5 feet 6 inches. All the slops from Nos. 1, 2, and 3 in the row, with the exception of chamber slops, are habitually thrown into the channel at the rear, and partly soak into the earth at the angle of the channel and partly flow to the gulley. The suds from the washing of the infected clothing washed at No. 1 might, therefore,

* This fact is on the evidence of the laundress, to whom the girl, who had not then gone to bed, apologised for the stained condition of her linen, saying that the diarrhœa was such that she could not help it.

have percolated into the well, and probably to some extent they did so. That percolation was possible is further shown by the evidence of the mother of the girl ill at No. 5, who says that at times the well water has been actually white after a washing day at No. 1. The infected evacuations also from the first case in the row at No. 2 were thrown into a midden privy only about 7 yards from the well, and probably assisted to infect the water through the permeable soil. The slops were thrown, as in the case of No. 1, into the channel at the rear. Up to the date of my visit to the cottages on February 12 no case of fever had occurred at the isolated cottage, although the occupants used the water from the same well. They say, however, that they never drank it cold, but only when made into tea. This cottage has a well of its own, but the water is so polluted from a privy within a few feet of it that it has been disused for a long time.

There can be no doubt that the origin of the fever in the cottages was due to the use of the well water, infected through the suds in which the infected clothing, &c., used by the fever patients in Moseley, had been washed, and that this infection first occurred in the course of the fortnight ending December 21.

On February 12 I recommended the removal of the handle of the pump connected with the infected well, and the Medical Officer of Health for King's Norton Rural Sanitary District has since informed me that this recommendation was at once carried into effect, and that a new well has been sunk and a good supply of water obtained. He informs me further that no fresh cases have occurred in any of the cottages since my visit.

At the period of my first visit to Moseley and Balsall Heath, in the beginning of January, it was evident that the spread of the fever in these places had already ceased, or nearly so. Either all the persons using the infected milk who were at the time susceptible to the operation of the virus had been attacked, or the wells upon the milkmen's premises had ceased to be infected. Nevertheless there was no ground upon which the latter alternative could be positively assured. At the same time there was yet a danger of the spread of the fever by emanations from the privies into which infected evacuations had been thrown, and by infection of the wells which derived their water from the polluted soil.

I therefore made the following recommendations for immediate adoption to the Rural Sanitary Authority of King's Norton (within whose jurisdiction Moseley is situated) and to the Local Board of Balsall Heath, at interviews which I had with these boards respectively, on January 9 and January 11:—

1. That, pending arrangements for a permanent supply of wholesome water, a temporary supply of water should be provided for the inhabitants from the waterworks of the Birmingham corporation, by means of stand-pipes, erected in convenient places; and that printed notices should be issued, recommending inhabitants no longer to use the water from their wells. In making this suggestion, I gave no opinion as to the general wholesomeness of the Birmingham supply, but advised its use on the ground of its being the best immediately available. This recommendation was at once carried into effect, so far as the provision of stand-pipes is concerned.
2. That steps should be taken to induce persons, having enteric fever

in their families, at once to disinfect the evacuations from the sick and soiled linen or articles of clothing, &c., and that the drains and privies of houses, where enteric fever had occurred, should be regularly disinfected, under the supervision of the officers of the authorities.

3. That the Local Board of Balsall Heath should adopt any means in their power to bring about the disuse of the wells upon the premises of the persons who had distributed the infection of the disease with their milk. The handles of the pumps attached to these wells were at once removed.

In addition to the above, I have to make the following recommendations for the improvement of the sanitary condition of both districts.

1. Proper sewers into which all premises may be properly drained should be provided under the direction of a skilled engineer, and, on their being provided, the dumb wells, into which domestic sewage is now carried, should be abolished.
2. Arrangements should be made for the frequent and systematic removal of the excrement of the population, in accordance with the principles laid down in the Office Report "On Means of preventing Excrement Nuisances in Towns and Villages."
3. The sanitary authorities of Moseley and Balsall Heath should provide for these places a sufficient supply of wholesome water, and, as soon as the state of the law may permit, all wells of unwholesome water should be abolished.
4. The attention of these authorities should be drawn to sections 22 to 27, and sections 37 to 39 of the Sanitary Act, 1866, which indicate the means which they should adopt, to deal with the outbreaks of infectious diseases. They should especially provide for the proper disinfection of infected houses and things, and, under the 37th section, a place of the nature of a cottage hospital, to which they may remove, under the 26th section, any persons (irrespectively of the question whether they are or are not paupers), so lodged as to be a source of danger to other persons in the same houses or neighbourhood.

Local Government Board, Medical Department,
April 1873.

Appendix.

Report on Two Samples of Water received from Dr. Ballard on January 16th, 1873. Each sample contained in two Winchester quarts. Stopper tied over and sealed; seals unbroken.

Both waters are turbid, very hard both before and after boiling, and contain a considerable amount of volatile matters and fixed salts. Both contain an excessive amount of ammonia, and also much nitrogenized matter, which, together with the high proportion of chlorine, and, particularly in the case of No. 2, the large amount of nitric acid, show very considerable contamination by sewage or surface drainage. The proportion of oxygen absorbed from permanganate is also rather high.

App. No. 5.

Enteric Fever at Moseley and Balsall Heath, by Dr. Ballard.

The following are the details of the analysis:—

	No. 1.	No. 2.
Appearances - - - - -	Turbid - -	Turbid.
Colour - - - - -	Pale yellowish brown	Brownish.
Deposit - - - - -	Slightly flocculent -	Slight.
Taste - - - - -	Mouldy - -	Mouldy.
Nitrous acid - - - -	Slight trace -	Strong trace.
Phosphoric acid - - -	Minute trace -	Strong trace.
Hardness on Clark's scale - -	54 degrees - -	48·7 degrees.
„ after boiling - - -	22·5 „ - -	48 „
	Grains per gallon.	Grains per gallon.
Oxygen absorbed from permanganate -	0·168	0·224
Total solids - - - -	70·56	131·86
Consisting of { Volatile matters -	16·00	32·37
Consisting of { Fixed salts - -	54·56	99·49
Chlorine - - - -	7·35	9·31
Nitric acid (N_2O_5) - - -	2·268	11·564
Nitrogen in ammonia - - -	0·490	0·350
Organic nitrogen - - -	0·0420	0·0525

A. Dupré.

Westminster Hospital, January 20, 1873.

No. 6.

App. No. 6.

Enteric Fever in West London, by Mr. Radcliffe and Mr. Power.

REPORT on an OUTBREAK of ENTERIC FEVER in MARYLEBONE and the ADJOINING PARTS of LONDON; by Mr. J. NETTEN RADCLIFFE and Mr. W. H. POWER.

This Report refers to the prevalence of enteric fever in certain districts of West London during the months of July and August last year (1873). The fact of this prevalence was first brought to the notice of the Medical Officer by Dr. Whitmore, the Medical Officer of Health for Marylebone, who submitted for consideration, and as calling for an inquiry extending over a wider area than the Marylebone district, communications made to him by Dr. Murchison and other medical men, respecting a series of attacks of households by enteric fever, apparently connected with the distribution of milk from a particular dairy. An investigation of these facts, made by one of us under instructions from the Board, and in conjunction with Dr. Whitmore and Dr. Murchison, extended to occurrences of enteric fever in 28 households, the greater number living in the districts of Marylebone and St. George's (Hanover Square), and yielded strong *primâ facie* evidence that these occurrences had been caused by the dissemination of enteric fever infection in the milk dealt out by the dairy referred to. The grounds of this conclusion and the immediate action taken upon it have been stated in a preliminary report made to the Board on the 15th August last (1873), and given in an Appendix.

In the present Report it is proposed to show the results of a more detailed investigation of the prevalence of enteric fever in the infected districts of West London during the months under consideration.

1. The inquiry extended to 244 cases of enteric fever,* distributed in 143 households. These cases all occurred during the nine weeks ending the 30th August, and, with few exceptions, they were limited to the districts of St. Marylebone, St. George's (Hanover Square), and Paddington; and there was a further limitation in St. George's (Hanover Square), to that portion of the district which lies to the north of Piccadilly; and in Paddington to that portion of the district which lies to the south and west of the Great Western Railway station.† By far the greater number, moreover, were confined to the households of well-to-do and wealthy people, 26 only happening in families not coming within this category.

* The total cases of "fever" reported to us exceeded this number, but undoubted cases of enteric fever only have been tabulated. The cases not considered were chiefly cases of undefined ailments or of diarrhœa, occurring in families exposed to the special cause of enteric fever presently to be described.

† Districts.	Households with Enteric Fever.	No. of Cases.
St. Marylebone - - - - -	77	145
St. George's, Hanover Square - - -	30	50
Paddington - - - - - - -	23	32
Hampstead (Belsize Park) - - -	1	1
St. Pancras (Regent's Park) - - -	3	3
St. Anne, Soho - - - - - -	8	12
Kensington (The Boltons, West Brompton) -	1	1
	143	244

App. No. 6.

Enteric Fever in West London, by Mr. Radcliffe and Mr. Power.

These cases took place at a time when there was no corresponding increase of enteric fever in neighbouring districts, and when the metropolis was, and had been for many weeks, remarkably free from the disease. They formed a well-defined localised outbreak. From the beginning of the year to the period of the outbreak, the mortality from "fever" in the metropolis kept continuously much below the average of the preceding 10 years, the average weekly deaths in this period being 24·6, as compared with an average of 46·4 during the 10 years 1863–72. While the outbreak was in progress a like low mortality continued, the average for the metropolis during the nine weeks of its persistence (from the twenty-seventh to the thirty-fifth week inclusive, ending respectively July 5 and August 30) being 27·4 weekly, as compared with 43·3 in the previous 10 years. After the outbreak, and to the close of the year, this low mortality continued, the weekly deaths once only reaching the average of the preceding 10 years, and once only exceeding it. In the fortieth week of the year the deaths were 43, the average being 42·7; in the forty-third week of the year the deaths were 55, the average being 49·0.

The state of enteric fever in the affected districts previous to the outbreak was similar to that observed in the rest of the metropolis. There was a general concurrence of medical opinion as to their freedom from the disease during the preceding six months. The returns of patients received into the different metropolitan hospitals to which fever cases from West London are commonly sent, were confirmatory of this opinion. Of 201 cases of enteric fever admitted into these hospitals within the period named, 26 only came from St. Marylebone, St. George's (Hanover Square), and Paddington.* The returns of deaths from fever for the three districts further confirm the conclusion which follows from the foregoing considerations.

From the first to the twenty-fifth week inclusive, the number of deaths in St. Marylebone was 19, as compared with an annual average of 31 for the same period during the five years 1868–72; in St. George's (Hanover Square), the number was 16, as compared with an annual average of 18·2; in Paddington, the number was 11, as compared with an annual average of 20·4. During the eight weeks preceding the outbreak the mortality from fever in St. Marylebone was 8, this being a fraction under the annual average number of deaths for the same period in the previous five years, namely, 8·6. In St. George's (Hanover Square), the deaths from fever in the corresponding weeks were 2, the average number annually, during the like period of the five preceding years, having been 6·6. In Paddington, the deaths were 4, as compared with an annual average of 4·6.

The returns of mortality confirmed the results of inquiry that the outbreak was almost solely limited to the districts of St. Marylebone, St. George's (Hanover Square), and Paddington. Taking the period from the twenty-sixth week of the year (ending June 28) to the fortieth

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* The Metropolitan Asylums District Fever Hospitals at Homerton and Stockwell receive a large proportion of the fever cases occurring among the pauper class of the several Metropolitan Districts. These districts are assigned as follows:—To *Homerton*, Shoreditch, Bethnal Green, Whitechapel, St. George's-in-the-East, Stepney, Mile End Old Town, Poplar, St. Marylebone, Hampstead, St. Pancras, Islington, Hackney, Holborn, and City of London.—To *Stockwell*, Chelsea, Kensington, Paddington, Bloomsbury, Fulham, St. George's (Hanover Square), Strand, and Westminster, in addition to all districts south of the Thames.

During the first six months of the year Homerton received 37, and Stockwell 59 cases of enteric fever.

week (ending October 4) inclusive (Table I.),* so as to bring in the later deaths from the outbreak, the mortality from fever was markedly in excess of the average in St. Marylebone, St. George's (Hanover Square), and in South Paddington (Table II.), within the area of the outbreak, although in the whole of Paddington the mortality during this period was a fraction below the average. Of the districts adjacent to those chiefly affected, in one only did the mortality from fever exceed the average of the previous five years. In Kensington the mortality was slightly in excess (11, as compared with 9·6); in Chelsea it was at the average; in the remaining districts it was below. The excess of mortality in Kensington, according to Dr. Dudfield, the Medical Officer of Health, was not dependent upon any special prevalence of enteric fever in that district, and did not exceed the usual variations observed from year to year during the ordinary presence of the malady.

The mortality from fever in the districts within the affected area, during the fifteen weeks under consideration, was nearly *one-third* above the average of the preceding five years, that is to say, 45 as compared

* Table I.—Deaths from Fever in the Metropolis and certain of its Registration Districts and Sub-districts from the 26th to 40th Week, inclusive, 1873.

Weeks ending—	Metropolis.		Kensington.		Chelsea.		St. Margaret's, Westminster (Sub-district).	
	Average, 10 Years, 1863–72.	1873.	Average, 5 Years, 1868–72.	1873.	Average, 5 Years, 1868–72.	1873.	Average, 5 Years, 1868–72.	1873.
June 28	39·1	20	0·4	1	0·4	—	1·0	—
July 5	41·3	24	0·4	—	0·6	2	1·0	1
„ 12	44·4	20	1·0	—	0·6	1	0·8	2
„ 19	43·3	21	0·6	—	2·0	—	0·0	1
„ 26	41·9	37	0·8	2	0·4	2	1·2	2
August 2	42·9	22	0·4	1	0·6	1	1·2	1
„ 9	41·8	25	1·2	—	0·2	—	1·4	—
„ 16	44·4	28	1·2	1	0·6	—	0·6	—
„ 23	44·7	32	0·6	1	0·8	—	1·6	1
„ 30	45·8	38	0·4	1	0·6	1	1·0	1
September 6	47·2	27	0·4	1	0·6	1	0·8	—
„ 13	49·8	26	0·8	—	0·8	—	0·4	—
„ 20	47·3	34	1·0	2	1·4	1	0·8	—
„ 27	47·6	39	0·2	1	0·8	—	0·6	—
October 4	42·7	43	0·2	—	0·6	—	1·0	1
	664·2	436	9·6	11	11·0	9	13·4	10

(*continued.*)

Week ending—	St. James's, Westminster (Sub-district).		St. Pancras.		St. Marylebone.		St. George's, Hanover Square.		Paddington.	
	Average, 5 Years, 1868–72.	1873.	Average, 5 Years, 1868–72.	1873.	Average, 5 Years, 1868–72.	1873.	Average, 5 Years, 1868–72.	1873.	Average, 5 Years, 1868–72.	1873.
June 28	0·8	—	0·8	—	1·2	2	0·0	2	1·0	—
July 5	0·6	1	1·0	1	2·2	—	1·0	—	1·2	—
„ 12	0·4	—	0·8	2	1·4	1	0·0	—	0·8	—
„ 19	0·8	—	0·8	—	1·6	2	0·0	—	1·8	2
„ 26	0·4	—	2·4	1	1·8	1	0·2	1	0·4	—
August 2	0·4	—	2·8	—	0·8	1	0·4	—	0·2	1
„ 9	0·6	—	1·8	1	1·6	1	0·2	1	1·0	—
„ 16	0·2	1	1·2	2	1·6	4	0·4	2	0·4	1
„ 23	0·2	1	1·4	2	0·8	2	0·6	—	1·0	3
„ 30	0·2	—	2·2	2	1·4	2	1·2	3	0·2	—
September 6	0·4	—	2·2	2	1·6	3	0·6	1	1·2	—
„ 13	0·6	—	3·6	—	2·0	3	1·4	1	0·8	—
„ 20	0·6	—	2·4	4	0·8	—	0·6	—	0·6	4
„ 27	0·4	2	3·2	3	1·2	1	1·2	—	0·8	—
October 4	1·0	—	2·2	3	1·6	1	0·2	1	1·0	1
	7·6	5	28·8	23	21·6	24	8·0	12	12·4	12

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with 34·2. The mortality in the several districts was as follows:—In St. Marylebone there were 24 deaths as compared with an annual average of 21·6 for the corresponding period of the previous five years, and in St. George's (Hanover Square), there were 12 deaths as compared with an annual average of 8 for a like period. In Paddington the deaths from fever throughout the whole district were 12, as compared with an annual average of 12·4 for the corresponding period of the previous five years, but 9 of these deaths took place in South Paddington (the registration sub-district of St. John), that is to say, within the area of the outbreak. If the mortality from fever in North and South Paddington respectively be compared, the following results are obtained (Table II.*) :—The mortality in North Paddington for the fifteen weeks was 3, as compared with an annual average of 7·8 during the corresponding period of the previous five years; while in South Paddington, the mortality was 9, as compared with an annual average for the same period of 4·6. In North Paddington, in fact, the mortality was very low, as in the rest of the metropolis outside the area of the outbreak; in South Paddington, within the area of the outbreak, it was exceptionally high. A like phenomenon was observed in St. George's (Hanover Square). Of the 12 deaths registered in that district during the fifteen weeks, 2 were of patients in St. George's Hospital who came from outside the district (1 from Chelsea and the other from Clapham), and 8 of the remaining 10 (5 of the 8 dying in St. George's Hospital) were of persons who contracted the disease within the area of the outbreak in St. George's.

Much trouble has been experienced in obtaining details respecting the different cases of enteric fever, and it has not been possible to procure these in all the cases. The outbreak occurred at a time when families of the class chiefly affected, and many medical men, leave town for the vacation. Several families carried the disease with them into the country, and it is not certain that all the instances in which this happened have been discovered. Other families sent servants, when sickening from the disease, to their homes in the country. Five of such cases were discovered, but we believe that there were other instances of the same kind. One of these cases was discovered by one of ourselves in the course of an inspection made in Buckinghamshire. This case had been sent from London to her home when the patient had been about seven days ill of

* Table II.—Deaths from "Fever" in Paddington, 1873.

Week ending		Average of 5 Years, 1868-72.		1873.	
		St. Mary (North.)	St. John (South.)	St. Mary (North.)	St. John (South.)
June	28	0·8	0·2	0	0
July	5	0·8	0·4	0	0
,,	12	0·4	0·4	0	0
,,	19	1·4	0·4	1	1
,,	26	0·4	0·0	0	0
August	2	0·2	0·0	0	1
,,	9	0·4	0·6	0	0
,,	16	0·4	0·0	0	1
,,	23	0·6	0·4	0	3
,,	30	0·0	0·2	0	0
September	6	0·4	0·8	0	0
,,	13	0·6	0·2	0	0
,,	20	0·2	0·4	1	3
,,	27	0·6	0·2	0	0
October	4	0·6	0·4	1	0
		7·8	4·6	3	9

the disease, and she died on the seventh day after reaching her home, death having probably been accelerated, at the least, by the long journey. We may remark here, in respect to the removal of these servants into the country, and assuming they had an objection to be removed to the wards of a general hospital, that both they and their masters appear to have been ignorant of the admirable accommodation for such cases in the London Fever Hospital. Such an objection, however, it is proper to remark, is exceptional, for not less than forty-three domestic servants who suffered in this outbreak were treated in hospital. These added to thirty-three cases not removed to hospital, but treated either at their places of service or at their homes in town, to the five cases discovered in the country, and to eleven occurring (in families removing from the affected districts) immediately after leaving town, make a total of ninety-two domestic servants attacked, that is to say, 37·7 per cent. of the whole number of ascertained seizures during the outbreak.

The total number of persons attacked after leaving London, and whose illness dates from before the time of their leaving, was thirty-three.

Not a few families left town for lengthened periods of absence as soon as the cases of fever in them became convalescent, and of several of these it has only been possible to obtain an authentication of the actual nature of the sickness and of its probable source.

Notwithstanding these difficulties we have got together the following particulars respecting the dates of attack, the ages, and the sex of the greater number of the cases; and we are of opinion that they fairly represent the progress of the outbreak and the peculiarities of its incidence upon individuals.

DATES of ATTACK in 191 Cases.

Date of Attack.	Cases.	Week ending.	No. of Cases in each Week.	Date of Attack.	Cases.	Week ending.	No. of Cases in each Week.
July 1	1			August 3	3		
" 2	1			" 4	7		
" 3	1	July 5	5	" 5	8		
" 4	1			" 6	9	Aug. 9	49
" 5	1			" 7	—		
" 6	3			" 8	11		
" 7	1			" 9	11		
" 8	1			" 10	2		
" 9	1	July 12	6	" 11	2		
" 10	—			" 12	2		
" 11	—			" 13	—	Aug. 16	7
" 12	—			" 14	—		
" 13	1			" 15	—		
" 14	—			" 16	1		
" 15	—			" 17	—		
" 16	3	July 19	11	" 18	1		
" 17	—			" 19	—		
" 18	4			" 20	2	Aug. 23	3
" 19	3			" 21	—		
" 20	18			" 22	—		
" 21	5			" 23	—		
" 22	8			" 24	—		
" 23	6	July 26	50	" 25	1		
" 24	8			" 26	—		
" 25	2			" 27	—	Aug. 30	1
" 26	8			" 28	—		
" 27	4			" 29	—		
" 28	15			" 30	—		
" 29	1						
" 30	3	Aug. 2	59				
" 31	14						
August 1	10						
" 2	12						

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Sex of 148 *adult* cases, and number of *children* attacked :—

Men	29	148
Women	119	
Children		96

Ages of 179 of the attacked :—

Under 5 years	14	20 and under 25 years	29
5 and under 10 years	35	25 „ 30 „	19
10 „ 15 „	29	30 „ 40 „	16
15 „ 20 „	29	40 years and upwards	8

Among the entire number of 244 cases, 26 deaths were ascertained to have occurred, 11 of which do not appear in the mortality return of the affected districts, 4 of these having taken place in the country, and 7 in hospitals situated in other districts of the metropolis.*

As already mentioned, the outbreak was almost entirely confined to the districts of St. Marylebone, to that portion of St. George's (Hanover Square), which lies to the north of Piccadilly, and to that portion of Paddington which lies to the south and west of the Great Western Railway station. There was a certain scattering of cases in the neighbouring districts of St. Pancras, St. Anne's, Soho, and Hampstead, which will be more fully described hereafter. Within the area of prevalence the disease was distributed somewhat irregularly in every part. The number of localities (including streets, squares, places, &c.) affected was 88, and of these 48 had only one case in them, the rest having two or more. The localities chiefly affected were 12 in number (Seymour Street, Old Quebec Street, Norfolk Square, Grosvenor Square, Grosvenor Street, Wigmore Street, Queen Anne Street, Wimpole Street, Nottingham Place, Gloucester Place, Lancaster Gate, and Granville Place), and in them occurred 108 cases, the remaining 76 localities having 136 cases. 76 houses had solitary cases, 67 houses had two or more cases.

2. In endeavouring to elucidate the causes of this outbreak of enteric fever, of its peculiar localisation, and of its limitation to a particular class of the population, attention was first given to the conditions of sewerage, drainage, and water supply of the affected districts and houses. The results of the investigation in these respects may be thus stated :—

As to Sewerage and Drainage.—(*a*) About one-tenth of the whole number of cases occurred in houses where there were obvious or presumed defects of drainage which might account for their existence. Among these cases was a group in one mansion which followed upon, and may have been determined by the importation of a case into the household from the Continent.

(*b*.) Certain other cases and groups of cases occurred in houses where some imperfections of drain traps were discovered, and a direct connexion of the waste pipes of the drinking water cisterns with the sewers. The suspicion was at first excited, particularly having regard

* Of those dying in the country, 2 from Marylebone died, 1 at Chipping Norton, the other at Dolgelly; 1 from St. George's died at Windsor; and 1 from Paddington died at Brill, Bucks. Of those dying in hospitals out of affected districts, 5 from Marylebone died, 1 in each of the following hospitals: London Fever Hospital, Islington; St. Bartholomew's Hospital, City; University College Hospital, St. Pancras; King's College Hospital; and the Metropolitan Asylum District Board Fever Hospital, at Homerton; 1 from Paddington died in University College Hospital; and 1 from St. George's, Hanover Square, died in St. Mary's Hospital, Paddington.

to the number of domestic servants attacked, that these cases also owed their origin to a probable pollution of the atmosphere, particularly in the basement of the houses, and of the water supply of the houses with sewer air. But as the inquiry proceeded it was found impossible to reconcile this view with the peculiar limitation of the disease to well-to-do and wealthy families occupying the most commodious houses in the affected districts. For the defects noted were common to these houses and to large numbers of neighbouring less commodious houses occupied by other and poorer classes of the population, the inhabitants of which wholly escaped the outbreak.

(*c.*) The greater number of cases occurring in certain streets, particularly in St. Marylebone, suggested that some temporary defects of main sewerage might be at the bottom of the outbreak; and information was communicated to us of reconstruction of sewers in the localities chiefly affected in St. Marylebone. But a return of the sewerage works carried out by the vestry of St. Marylebone, which has been prepared for us by the assistant-surveyor to the vestry, Mr. Hallett, shows that the sewerage works referred to had all been completed on or about the 20th April, two months before the outbreak. The inquiry failed to elicit any evidence of defective sewers in connexion with the outbreak.

(*d.*) Several groups of cases occurred under circumstances peculiarly favourable for complete observation. In two of these groups, both of them occurring in the households of medical men, accustomed to etiological research, it was possible to put aside, with as great a certainty, perhaps, as can ever be attained in such inquiries, the questions of pollution of the atmosphere and of the water supply of the house with sewer air. In each instance the drainage of the house had, some time before the outbreak, been placed in as thorough order, with special reference to the exclusion of sewer air from the interior and from the water cisterns, as sanitary science could teach and good workmanship and supervision command. So far as human foresight could provide, both houses were sealed against enteric fever, and, unless the disease were contracted away from home, the households were secure against the malady. In one of these households three cases, and in the other six cases, of enteric fever occurred, in each instance determined, apparently, by the same cause (whatever that might be), acting about the same time. The probability of the disease having been contracted away from the houses by any one of the sufferers in either household could be set aside with almost absolute certainty; but any doubt which might rest upon this matter was, by the circumstances of the cases, completely disposed of, as of the majority it could be confidently affirmed that it was impossible for the disease to have been contracted away from home.

Another group of cases, also taking place in the family of a medical man, occurred during the outbreak under the following circumstances:—Earlier in the year five members of the family had suffered from the disease. These cases were attributed to marked imperfections in the drainage of the house. On their recovery the family left town for a time, and during their absence the drainage of the house was put into thorough order. Shortly after returning home three other members of the family were attacked with the disease. The dates of seizure forbid the supposition that they had contracted the malady whilst in the country. The recent rectification of the drainage of the house appeared equally to forbid the assumption that the disease had been occasioned by defects of drainage. Further, it was improbable that the disease could have been contracted elsewhere in the metropolis.

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A fourth group of cases took place in a charitable institution for young children. 18 out of 30 of the little inmates were attacked. Two apparently disconnected cases preceded the wider prevalence in the establishment, and at once gave occasion for the most careful examination of the sanitary arrangements of the building by the medical attendant. These were found to be unimpeachable. Two years before, a solitary case of enteric fever occurring among the children alarmed the managing committee. As a consequence the whole of the drains of the building had been reconstructed, and the rain pipes, waste water pipes, and sink pipes cut off from direct communication with them. In the spring of the present year the building was put in order throughout, and, among other things, the state of the drain inlets, and of their traps, and of the water closets was seen to. In the interval of these structural repairs the sanitary state of the building was under the constant supervision of the medical attendant; and he was able to determine fully that at the time of the outbreak among the children the drainage arrangements and the water supply were, and had been for some time, in perfect order.

The foregoing considerations appear to us to lead irresistibly to the conclusion that defects of drainage will account for a very small proportion only of the cases which occurred during the outbreak which forms the subject of this report.

As to Water Supply.—The question of a pollution of the water supply in the several houses affected with enteric fever has been dealt with in the previous section. We have here to consider the questions of pollution of the general water supply and of local branches of supply. Both these questions admit of being very briefly touched upon. The area of the outbreak was within the districts of two metropolitan water companies, the West Middlesex and the Grand Junction. The area occupied a small segment of the last-named company's district, and a much larger portion, but far from the whole field, of the first-named company's district. Both companies take their water from the same point of the Thames. The distribution of the cases, indeed, proves that there was no general infection of the water supply.

One of us had in mind the accidental pollution by sewage, several years ago, of a local branch supply of one of the companies named, and, notwithstanding the extreme improbability of concurrent and adjacent local pollutions in the districts of the two companies, inquiry was made as to the occurrence of any such pollution during the outbreak under consideration. There was not a particle of evidence to show that pollution of any branch supply had happened, either at the time or immediately before the time of the outbreak.

3. Still proceeding by a process of exclusion it was necessary to examine the relations which the outbreak might have to the considerable prevalence of diarrhœa in the metropolis about the same time, and to certain meteorological phenomena. (*See* Appendix, Table I., Diagrams 1 and 2). It seemed probable that we might thus, indirectly, gain some light upon the main object of the inquiry. The mortality from diarrhœa in the metropolis, which had steadily remained below the average of the preceding 10 years until the 30th week of the year (ending July 26), went largely above the average in the 31st and 32nd weeks (ending August 2 and August 9 respectively), and kept steadily above it until the close of the 41st week (ending October 11). This augmentation of the mortality of diarrhœa above the average followed close upon certain well-defined meteorological changes.

According to the Greenwich observations, as summarised by Mr. Glaisher in the Registrar General's quarterly returns, we learn that

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" from the 22nd day of April a long cold period set in, and the weather " continued, with but few trifling exceptions, continually below the " seasonable average till the 18th day of June. For this long period " of 57 days the deficiency of mean was, on the average, $2\frac{3}{4}°$ daily. " On the 19th of June a warmer period set in, but not uninterruptedly, " for four out of the remaining 12 days were of lower temperature than " was due to the season. Upon this period of 12 days there was a " mean excess of daily temperature of $1\frac{1}{4}°$." The mean temperature of the month, 58·9°, was 0·7° higher than the average of 102 years; the daily range of temperature was less than the average by 1·0°. Frequent movements of the barometer occurred in June, but only to small amounts, and the mean reading of the month (29·794) was 0·020 below the average. The prevalent winds were southerly and south-westerly, and the rainfall (2 inches) was 0·7 in excess.

The following month, July, the weather till the 19th " was mostly " cold, and the mean daily temperatures were below their seasonable " averages by $\frac{3}{4}°$. On July 20 a sudden change took place, and for a " few days the weather was fine and hot, particularly on the 21st, " 22nd, and 23rd, the mean temperature of those days being 71·7°, " 75·2°, and 72·3°, exceeding their averages by 10·2°, 13·7°, and 10·7° " respectively. Immediately following these four warm days, beginning " July 20, 1873, the weather was again cold, and from July 20 to " September 2 the weather was changeable, the whole period being " characterised by several days of warm weather, followed by a few " days of cold, and then succeeded by several warm days again; the " warm days were, however, the more numerous, and upon the whole " period there was an excess of temperature averaging $2\frac{1}{2}°$, on the 45 " days ending September 2." The mean temperature of July, 63·4°, was 1·8° higher than the average of 102 years, and $4\frac{1}{2}°$ above that of June; the daily range of temperature during the month was greater than the average by 1·7°. The readings of the barometer were very variable throughout the month, but the movements were not of very great magnitude; the mean reading (29·792) was 0·015 below the average. The prevalent winds were south-westerly, and the rainfall (2·5 inches) was the average

The sudden and great increase of temperature from the 20th to the 23rd July inclusive was immediately followed by a large augmentation of diarrhœa, marked by a considerable leap of the mortality from the disease in the week following (ending August 2) to 51 above the average of the previous 10 years; and the continuation of the high temperature was accompanied by a still greater augmentation in the next week after (ending the 9th August), when the deaths were 470, as compared with an average of 273·5 during the 10 years 1863–72. The mortality for diarrhœa continued above the average eight weeks following the week last named.

St. Marylebone, St. George's (Hanover Square), and Paddington, suffered from this increase of diarrhœa, as the rest of the metropolis. The mortality from diarrhœa in St. Marylebone exceeded the average of the previous five years, from the 31st to the 35th week, and again from the 37th to the 39th week inclusive; in St. George's (Hanover Square), it exceeded the average in the 32nd, 33rd, 34th, 36th, and 40th weeks; and in Paddington the 30th, 31st, 32nd, 34th, 35th, and 38th weeks.

The conditions which proved so favourable to the development of diarrhœa throughout the metropolis generally, were not correspondingly favourable to the development of enteric fever. As already stated in the first part of this report, the mortality from " fever " was remarkably low throughout the whole period in question, until the 40th week, when the average was reached. It had been, as a rule, largely below the average in each of the previous weeks of the year. The 40th week,

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when the deaths from "fever" reached the average of the preceding 10 years, was the last week of the mortality from diarrhœa remaining above the average. But that the prevalence of enteric fever was not uninfluenced by the high temperatures of July and August, is to be inferred (making due allowance for period of incubation and sickness) from the steady increase of mortality from "fever," with one fluctuation, from the week ending the 20th September to the week ending the 25th October, the only week in which the mortality exceeded the average throughout the year.* (*See* diagrams, Appendix.)

If, now, the progress of the outbreak in St. Marylebone, St. George's (Hanover Square), and Paddington, be compared (*see* Diagram, Appendix) with the meteorological phenomena which have been described, and with the progress of "fever" and diarrhœa throughout the metropolis, as gathered from the mortality caused by the diseases included in these terms, very marked differences are observed. First, it will be noticed, on reference to the dates of attack, that the beginning of the outbreak preceded by three weeks the great increase of temperature in July, the cause of the first seizures dating from a still earlier period. Next, the greatest number of seizures were crowded together in the three weeks of highest temperature, those ending the 26th July, 2nd and 9th August, in which weeks the great development of diarrhœa occurred, and the increasing prevalence of "fever" began in the metropolis generally. The crowding together of the seizures within these three weeks proves that the cause producing them was principally active during the preceding three weeks. Further, the outbreak quickly declined, and came to an end before the augmentation of the disease in the west of the metropolis could be definitely measured.

The phenomena of the outbreak, as to its inception, its rapid progress and development, and its quick decline, were quite apart from the phenomena of the progress and decline of fever elsewhere in the metropolis. These facts, and especially the circumstances that the outbreak preceded those local changes of temperature which so obviously determined the great prevalence of diarrhœa and affected the course of fever in other metropolitan districts, tend to confirm the conclusion which is to be derived from the considerations advanced in previous sections that the outbreak was not of local origin. It is to be inferred that, if the outbreak had been to any marked extent dependent upon local defects of sewerage and drainage, that the evil influence of these imperfections would have been exaggerated and prolonged by the excessive temperatures of July and August. The observed facts of sewerage and drainage in reference to the outbreak, and the relations of the outbreak to the movement of "fever" elsewhere in the metropolis, and to the meteorological phenomena of the period, concur in showing that its origin must be looked for in some cause other than one of local origin.

4. To this point the detailed investigation has confirmed the accuracy of the provisional conclusions of the preliminary inquiry. It now remains to be seen whether the ultimate conclusion of that inquiry is sustained by the additional and more closely observed facts collected. We have exhausted the known conditions which foster or determine the prevalence of enteric fever with one important exception, namely, the possibility of distribution of the infective material of the disease with some article of food. According to present experience this question is limited to the distribution of the infective material in *milk*.

Early in the outbreak Dr. Murchison, whose family suffered very

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* The excess of the mortality registered from "fever" during the week ending the 25th October (55 as compared with 49) was probably an accidental circumstance connected with registration. The average mortality from "fever" of the three weeks of which it was the middle was 43, as against a decennial average for the same three weeks of 50.

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severely from it, satisfied himself that the only probable mode of introduction of the disease into his house was by the milk supply. The suspicion having been aroused, he quickly ascertained that almost the whole of the families which were then affected with enteric fever within his knowledge and that of his professional friends, obtained their milk from the same dairy which supplied his household. The information as to these cases, communicated by Dr. Murchison to Dr. Whitmore, and by the latter gentleman to the Medical Officer, formed the groundwork of the preliminary departmental inquiry. Dr. Whitmore continued the investigation begun by Dr. Murchison, within the area of his own district and discovered much to confirm Dr. Murchison's conclusion. We have now to state the results of our further inquiry concerning this question, including the facts collected by Dr. Murchison and Dr. Whitmore, also by Dr. Corfield, and aided by the books of the implicated dairy, placed freely at our disposal for use in the inquiry by the proprietors, who, it must be added, in other ways also rendered us important assistance.

(*a.*) Of the 244 cases of enteric fever to which the inquiry extended, 218 (that is to say, *nine-tenths*) were in households which consumed milk obtained from a particular service of a particular dairy. The proportion of cases thus occurring in households using a particular milk-supply rendered it probable that the connexion between the milk-supply and the prevalence of fever was not casual.

(*b.*) This probability was strengthened by the progression of the cases in households having milk from the particular service, as contrasted week by week, with the cases in households having milk from other sources. This is shown in the following Table, compiled from the ascertained dates of attack:—

Table III.

Weeks ending	No. of Cases.	Of these there were	
		In Households taking Milk from the particular Service.	In Households not taking it.
July 5	5	1	4
„ 12	6	2	4
„ 19	11	11	0
„ 26	50	49	1
August 2	59	53	6
„ 9	49	46	3
„ 16	7	5	2
„ 23	3	0	3
„ 30	1	0	1
Total for 9 weeks	191	167	24

(*c.*) The disproportionate growth of cases in households having the particular milk-supply, as compared with those occurring in households not having this supply, shown in the foregoing Table, was still more clearly observed in the cases of enteric fever admitted into the different hospitals receiving cases from the affected districts; and the probability that this predominance was directly connected with the milk-supply was proportionately confirmed. The following Table (*Table* IV.) refers to cases of enteric fever received into certain London hospitals from the 1st January to the 1st September, 1873. These cases are separated into three categories. The first relates to cases received from the 1st January to the 30th June, that is to say, prior to the outbreak; the second relates to cases received from the 1st July to 1st September, that is to say, during the period of the outbreak. In the first two categories

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the cases received from the localities within the area of the outbreak are distinguished from those received from localities outside this area. The third category relates to the cases received from localities within the area of the outbreak, and among these distinguishes the cases in which the patients had habitually, before being attacked with enteric fever, consumed milk obtained from the particular service of the particular dairy referred to, from the cases in which the patients had not at any time consumed milk from this scource of supply. The results of the cases thus tabulated are as follows :—

1. Of 134 cases of enteric fever received into the hospitals named, during the six months ending the 30th June, 1873, 15 only came from localities situated within the area of the outbreak during July and August, and having, in round numbers, a population of a third of a million ; 119 coming from other localities having a population of upwards of a million, and also from East London.
2. Of 141 cases of enteric fever received into these hospitals during the two months ending the 1st September, the period of the outbreak, 64 came from localities situated within the area of the outbreak and 77 from other localities.
3. Of the 64 cases noted in the previous category as coming from localities situated within the area of the outbreak, 52 habitually consumed milk obtained from the particular service of the particular dairy previously referred to, and 12 had not at any time consumed milk from this source of milk supply.

The defined character of the outbreak is shown by the very largely augmented proportion of cases received into the hospitals named, during the two months ending the 1st September, from the affected area. The probability that the great increase of cases from this area might be dependent upon the quality of the milk-supply was clearly indicated by the excessively high proportion (a proportion, namely, of 13 to 3) of patients who, previous to the time of seizure, had been accustomed to use milk from one source of milk-supply as compared with patients who were accustomed to use milk from other sources of supply.

TABLE IV.—CASES of ENTERIC FEVER received into certain London Hospitals, January to September 1873.

Hospitals.	Jan. 1 to Sep. 1	Jan. 1 to June 30.			July 1 to Sept. 1.			Area of Outbreak, July 1 to Sept. 1.		
			Of these there were from—			Of these there were from—			Of these there were—	
	No. of Cases.	No. of Cases.	Area of Outbreak.	Other Localities.	No. of Cases.	Area of Outbreak.	Other Localities.	No. of Cases.	Taking Milk from a particular Supply.	Taking Milk from other Sources of Supply.
Charing Cross	6	3	1	2	3	2	1	2	2	—
Homerton	76*	37	1	36	39†	12	27	12	6	6
King's College	18	9	2	7	9	4	5	4	4	—
London Fever	32	22	1	21	10	4	6	4	4	—
Middlesex (to Sept. 13)	43	18	3	15	25	17	8	17	13	4
St. Bartholomew's	24	10	0	10	14	2	12	2	2	—
St. George's	34	15	2	13	19	8	11	8	7	1
St. Mary's	9	4	2	2	5	4	1	4	4	—
St. Thomas's	19	10	1	9	9	3	6	3	3	—
University College	14	6	2	4	8	8	—	8	7	1
	275	134	15	119	141	64	77	64	52	12

* A large proportion of these 76 cases in Homerton came from East London.

† Of 20 cases admitted into Stockwell (the other Metropolitan Asylum District Fever Hospital for pauper patients) during July and August, one only came from the area of outbreak.

(*d.*) The probability of this dependence of the outbreak upon the quality of the milk-supply among the households of the persons attacked became greater, when the distribution of the cases was examined in conjunction with the distribution of the particular milk-supply. With one remarkable exception, in Pimlico, presently to be described, wherever the milk of this supply was distributed there the cases of enteric fever which collectively formed the outbreak were distributed. Where the milk-supply stopped short there, as a rule, these cases stopped short. The map of the distribution of the milk-supply represented very closely the area of the outbreak; and that this was not an accidental correspondence was to be inferred from the following facts :—

(1.) The milk-supply in question was distributed generally over St. Marylebone, and that part of St. George's (Hanover Square) which lies to the north of Piccadilly, so also was the outbreak.

(2.) Certain ramifications of the milk-supply extended to the east side of Regent's Park, St. Pancras, to Belsize Park, Hampstead, to St. Anne's, Soho, and to several houses in St. James's, Westminster, and in these several localities, with the exception of St. James's, Westminster, the cases of enteric fever occurring during the outbreak which have come to our knowledge were, with one exception, among families having this milk-supply.

(3.) This milk-supply was also carried into South Paddington, as far west as Lancaster Gate and the streets adjacent. To this part of Paddington, and this part only, did the outbreak extend.

Here then, was an apparent explanation of the cases of enteric fever occurring during the outbreak, and obviously belonging to it, in limited parts of districts adjoining St. Marylebone and St. George's (Hanover Square). Here, again, also was an apparently sufficient explanation of the peculiar limitations of the area of outbreak.

(*e.*) Confirmatory of such an explanation was the fact that the distribution of the same milk-supply would equally explain the further and peculiar limitation of the outbreak to well-to-do and wealthy families. For this milk-supply was, with a remarkable exception presently to be mentioned, confined to such families, with the sole qualification of an occasional accidental issue by the carriers on their rounds.*

(*f.*) More direct evidence of a connexion between this milk-supply and the determining cause of the outbreak is furnished by the fact that the disease picked out the streets to which the milk was distributed, and the houses in those streets which received the milk. Of 88 infected streets this milk-supply went into 77, and of 132 infected houses in the 77 streets in which fever occurred, 14 only did not receive this milk-supply. In 118 houses out of 760 (15·5 per cent.) taking the milk there were 218 cases of enteric fever, while in the 14 houses, out of (in round numbers) 23,000 in the same area not taking the milk there were 14 cases only.

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* In the districts above mentioned, of 207 cases in connexion with this milk-supply, 4 only (not including servants) did not come within the category of wealthy and well-to-do people; while of 25 cases in the same districts not in connexion with the particular milk-supply, no less than 10 were of the poorer class. In other words, the cases among the poorer class in connexion with the milk were 1·9 per cent.; not in connexion with the milk, 40 per cent.

(*g.*) Still more direct evidence to this end, though in its nature limited in amount, is afforded by the disease during the outbreak having picked out the members of certain families using this milk-supply who alone drank the milk "as it came from the dairy," and by the seizure of persons who had exceptionally used it. The following are examples of both kinds of facts :—

Instances of first class cases.—(1.) The mistress and the kitchenmaid were the only persons in a family who habitually drank uncooked milk : they both had enteric fever. Two children in the same family who did not take milk in this form escaped. (2.) A physician, in the habit of taking nightly half a pint or more of cold milk, "as it came from the dairy," was the only person in his household who did so; he alone had enteric fever. (3.) Miss H., the only person in the house who drank cold milk, "drank it largely;" she had enteric fever. Other and similar instances might be mentioned.

Instances of second class of cases.—(1.) Miss N., early in July, paid a visit to her aunt in Marylebone; drank much milk while in town; returned to her home in the country July 23; fell ill with enteric fever July 26. (2.) Of a family consisting of a lady and three servants, the lady took milk from the particular dairy in question, while the servants were supplied from another dairy. One of these servants, the cook, "now and again" drank milk left at table by her mistress, she had enteric fever. (3.) In another household the master and mistress took milk from this particular dairy, while the servants (four), obtained theirs from a different source; one of these latter had enteric fever. She states that, "some days before she was taken ill" she drank half a pint of milk left at table by her master and mistress. There is reason to believe that in both these instances (3 and 4) the employers were middle-aged or elderly, while the servants were young persons. (4.) J. A., clerk to the dairy company in question, lived with his parents, who did not take the company's milk. During office hours, J.A. drank, he says, much milk; early in August he was attacked by enteric fever. There not any illness among other members of his family. (5.) A child, member of a family not dealing with this particular dairy, spent an afternoon (July 19) with a family supplied from this dairy, and during the visit drank nearly two pints of milk; on the 24th of July she was attacked by enteric fever. Of the family at whose house she spent the day 10 members were attacked by the same disease between July 21 and the beginning of August.

(*h.*) Other evidence tending to fix directly the dependence of the outbreak upon the quality of this milk-supply was furnished by numerous instances of seizures among large consumers of the milk. The following examples may be given :—

Instances. Adults.—(1.) A footman and a lady's maid, aged respectively 19 and 28, "were in the habit of drinking cold milk in considerable quantities during the hot weather;" both had enteric fever and the footman died. They were the youngest of a household of six persons. (2.) A kitchenmaid in a family of six persons, all adults, "did not drink beer, but often took draughts of milk;" she alone of the family was attacked by enteric fever. (3.) A cook, aged 20, was fond of milk and "often drank the milk left at table;" she alone, of a family of six adults, had enteric fever. The other servants, she says, "did not care for milk." (4.) A servant, aged 40, was in the habit of drinking much milk; she alone, of all the adults in the family (11), had enteric fever. Of three children in the same family two had enteric fever. (5.) A servant, aged 22, "was very fond of milk and often drank it cold;" she would drink the milk left at table; she died of enteric fever. Of two children in the same family, one, who was particularly fond of milk, and who often drank it "as it came from the dairy," also had enteric fever, but, after severe illness, recovered. (6.) A servant, aged 17, was a great milk drinker, and habitually drank the milk left at table, she died of enteric fever. A child in the same house was also attacked, but recovered. (7.) Two servants, each aged 23, were great milk drinkers; one "was in the habit of drinking much milk, as she did not take beer;" the other "was very fond of milk, and often drank it cold in hot weather." These servants were the only members of a

family of 12 adults attacked by enteric fever. (8.) In a family of 12 (seven adults and five children) the nursemaid (aged 17), "like the children often took draughts of cold milk." This nursemaid, the cook, and four chilldren, had enteric fever. (9.) A butler, who was a teetotaller and a great milk drinker, was attacked by enteric fever and died. (10.) A clergyman who was a milk drinker, took habitually two tumblerfuls of milk daily: he died of enteric fever. Other instances of the incidence of enteric fever on adults, who were large consumers of milk, could be given were it necessary.

As regards children, into whose diet milk naturally enters so largely, it has been found difficult to separate "milk drinkers" from those who did not habitually take milk in considerable quantity. Two instances may, however, be noted where a certain separation was effected. (1.) Of four children in a family, the second a girl aged five, was the only one who drank a great deal of milk; she alone had enteric fever. (2.) Of three children in another family the eldest had tea for breakfast and orange wine and water at night, the two younger ones having bread and milk for breakfast and cold milk at night; the two younger had enteric fever while the eldest escaped. In this family a butler, "who had beer money but saved it," had also enteric fever.

(*i.*) The assumption that this milk-supply occasioned the outbreak was consistent with the facts of the large number of women and children, and the small number of men affected by it.

The cases first observed were among children and women using a special milk issued from the dairy, and known as "nursery milk." Of 34 individuals, 12 being adult women and 22 children, belonging to six different families, who habitually used "nursery milk," 6 of the women (50 per cent.) and 7 of the children (31·8 per cent.) were attacked with enteric fever. At first it was suspected that this particular milk was alone infected, but, as the inquiry proceeded, it was ascertained that the cases were not confined to families using "nursery milk," but that they occurred also among families using the ordinary milk distributed from the dairy. The clue furnished by the "nursery milk" would (as subsequent inquiry proved) have sufficed to conduct the search for the source of infection to a successful issue, had any obstacle arisen in carrying out the method of investigation adopted.

(*j.*) Finally, evidence confirmatory to a very high degree of a direct connexion between this milk-supply, and the outbreak was furnished by an isolated group of cases which occurred at the same time in another district of the metropolis, namely, St. Anne's, Soho. These cases first came to the knowledge of Dr. Coupland, the Medical Registrar of the Middlesex Hospital; and, seeking for information as to their cause he found that several of them stated that they used milk obtained from a branch establishment in Soho of the dairy, the milk of which was suspected to have caused the outbreak in St. Marylebone, St. George's (Hanover Square), and Paddington. An inquiry into the conditions under which this group of cases had occured, made by one of ourselves, in conjunction with Dr. Conway Evans, the Medical Officer of Health for the district in which the locality is situated, led to the following results:—The cases were 12 in number, distributed in eight families, and the persons affected, chiefly children and young people, were not of the poorest class in the neighbourhood. No local cause could be assigned for the peculiar grouping of the cases. Eleven of the patients had, however, habitually or occasionally, milk from the branch establishment referred to. This establishment had been opened chiefly for the disposal of skim milk, and its business was conducted entirely across the counter, there being no delivery from it at customers' houses. The number of families buying milk from this establishment probably did not exceed 30, and of these seven were attacked with enteric fever. It would be difficult to regard the connexion of the cases in this group through

their milk supply, even if the evidence were weaker on the whole question than it is, as a mere coincidence.

Notwithstanding the high degree of probability attached to the conclusion which appears necessarily to follow from the preceding considerations, namely, that the outbreak was directly dependent upon the quality of a particular milk-supply, before adopting this conclusion it was necessary to examine certain facts which seemed to militate against it. These were,—

1. The exemption of certain families, 63 in number not living within the area of the outbreak but within the district of a branch dairy in Pimlico, who received their milk from the implicated dairy.
2. The freedom from the outbreak of the milk carriers engaged in distributing this milk supply.
3. The entire escape of many streets within the area of the outbreak to which the service of the particular milk supply extended.
4. The irregular distribution of cases within the area of the milk supply, particularly the marked predominance of cases in some streets (already named) as compared with others.

An examination of these facts has served to confirm the accuracy of the conclusion that follows from the great body of the evidence. At the commencement of the inquiry, observation of the manner in which milk was received from the country at the implicated dairy, led to the inference that, to explain the then known facts of the outbreak, it was not necessary to assume that the milk from more than one of the several farms from which the dairy obtained its supplies was infected with enteric fever material. This assumption has been fully justified by the results of further investigation. Such investigation has shown, as will be related in another part of the Report, that the infected milk came from a farm which, in addition to supplying somewhat over one-sixth of the ordinary milk received by the implicated dairy, supplied also the whole of the so-called "nursery milk." This last-named milk formed, on an average, $\frac{1}{22}$nd of the total milk supplied to the dairy, and it differed from the ordinary milk not so much in quality as in mode of collection and distribution.

The "nursery-milk," indeed, was milk collected from three or four cows selected and set apart from the general herd for the purpose. It was sent to London in a separate "churn," and was issued to customers from the dairy only on special request made for it, and then it was distributed in "sealed" cans in the quantities required. Although designated, for convenience, "nursery-milk," this milk was not invariably used for nursery purposes. It was retailed at the same price as ordinary milk, and it was designed to meet the desire of those customers who had an objection to the mingled milk of many animals for nursery or other use. The quantity of "nursery-milk" supplied to the dairy night and morning, from day to day, for several months before, and at the time of the outbreak had not varied.

It has already been stated that suspicion first fell upon the "nursery-milk" as being, of the two different kinds of milk issued by the implicated dairy, that alone which was infected; but that it was presently observed that the ordinary milk could not be exempted from suspicion. Further investigation has tended to prove, not only that the first suspicion was correct, but that the ordinary milk was infected only to such extent as "nursery-milk" might have become mixed with it. An examination of the manner in which "nursery-milk" was distributed from the dairy at the period which concerns this inquiry, while confirming the suspicion which first attached to it, furnished the clue to an

explanation of the facts which apparently militate against the conclusion that the outbreak of fever was dependent upon the quality of the milk distributed from the dairy under consideration. The first step in the elucidation of the difficulties which appeared to beset this conclusion, was a study of the exemption from the outbreak of the 63 families living in Pimlico who received milk from the implicated dairy. It has been clearly ascertained, that during almost the entire period occupied by the inception and progress of the outbreak, the whole of the ordinary milk obtained from the farm from which the "nursery milk" also came, was distributed among these families. This fact excludes from suspicion of infection the ordinary milk coming from the farm in question. The exemption of these families removes also suspicion of infection of such other ordinary milk as may from time to time have been sent to them from the implicated dairy during the progress of the outbreak. But during the several weeks within which the outbreak was developed, ran its course, and came to an end, no "nursery-milk" whatever was sent from the implicated dairy to these families, and consequently they did not receive at any time any portion of the milk upon which suspicion first fell during the period of its presumed infection. No "nursery-milk," moreover, was distributed to the milk carriers, who were also exempted from the outbreak. These carriers had among them, for the use of themselves and families, as a rule, only such milk as they brought back from their several beats. This milk was first placed in one of the mixing-vessels of the dairy, and then divided among the different carriers. As "nursery-milk" was only issued from the dairy in the quantities required by separate families, each quantity in its own sealed can, no "nursery-milk" was ever brought back by a carrier. The only occasion when "nursery-milk" could find its way into the carrier's portion would be when the dairy superintendent might, if the portion were deficient, add a small quantity to it from surplus "nursery-milk" in the dairy; but this, it is stated, could have happened very rarely.

On the assumption that the "nursery-milk" was alone infected, the foregoing exemptions are readily explained. The same assumption, when regarded in the light of the facts now to be recorded respecting the distribution of the "nursery milk," furnishes an equally reasonable explanation of the other difficulties which have to be considered.

It has already been stated that the quantity of "nursery-milk" received at the implicated dairy did not vary from day to day. This quantity was calculated to meet the maximum requirements of the dairy, but these requirements only existed during a limited portion of the year when the general demand for milk was also at the greatest. When the pressure of business diminished, concurrently with the departure of customers from town at the close of the season, a surplus of "nursery-milk" remained undisposed of as such, and was dealt with in one or more of the several ways following :—It was either (*a*) "set" (as the phrase is) for cream ; or (*b*) it was sent into the shop to be sold across the counter; or (*c*) it was used to supplement the general supply if it fell short. If "set" for cream, the skim milk would be sent to the Soho branch to be retailed there. If used to supplement the general supply, it was not mixed generally, or even to any considerable extent, with that supply. It was added to one of the last-served carrier's cans.

An examination of the books of the implicated dairy shows that the pressure of business in 1873, after fluctuating slightly during the weeks ending the 28th of June and 5th of July, steadily diminished during and after the week ending July 12th; nearly one-half the customers

who had left town prior to the last-named date being habitual consumers of nursery milk. From the 12th of July, and probably for several days previous, there would be a surplus of "nursery-milk," increasing in amount day by day as the pressure of business declined, to be dealt with in one or other, or all, of the ways just described. The Soho branch would then receive from time to time skim milk from the "nursery milk," and the customers of that branch be brought within the influence of the assumed infecting agency. From time to time also portions of "nursery milk" would find their way to the counter of the implicated dairy. We have related one case of infection presumably from milk drunk from the counter, and we refer to another believed to have been contracted in the same way. We believe, also, that several cases of enteric fever occurring in streets adjoining the implicated dairy, but not among regular customers of the dairy, are to be accounted for by the use of milk or cream purchased across the counter of the dairy at the time of the outbreak. Finally, the occasional supplementing of a deficient general supply by the "nursery milk" in the manner which has been described, would abundantly explain the infection of the general milk supply. From the limited extent, moreover, to which the general supply would be thus supplemented (never extending beyond an addition to a particular carrier's can at a given time), together with the fact that the "nursery milk" itself in its distribution did not find its way into the greater number of streets supplied by the implicated dairy, a clear explanation is forthcoming of the escape of many streets from the outbreak, and of the irregular distribution of cases within the area of the milk supply, as well as of the marked predominance of cases in some streets as compared with others.

The outburst of the fever among the households consuming ordinary milk occurred at the time when "nursery milk," as gathered from the books of the dairy, passed into the general distribution. This, as already stated, would happen in considerable quantity during the week ending the 12th July. On the second week following (ending 26th July), after the ordinary incubative period of the disease, the first attacks of enteric fever among households using ordinary milk, increased from an average of 5 per cent. in the three previous weeks to 86 per cent., that is to say, 17 times above that average. That this increased incidence upon households consuming ordinary milk was not owing to an augmented virulence of the infective agency, is to be inferred from the fact that among households consuming "nursery milk" the outburst of fever occurred a week earlier, namely, in the week ending 19th July, when the number of attacks of these households increased from 8 per cent. to 33 per cent.

5. From all the foregoing considerations, we have come to the ultimate conclusion that the probability of the outbreak of enteric fever under consideration having been caused by an infected milk supply, amounts for all practical purposes to a certainty. The results obtained in this respect from the detailed investigation have confirmed fully the opinions formed from the preliminary inquiry. We have now to state the results of the further investigation as to the probable source of infection of the milk. The action taken to this end, in conjunction with Dr. Whitmore, Dr. Corfield, the Medical Officer of Health for St. George's (Hanover Square), and Mr. J. Chalmers Morton, is related in the Appendix. Subsequent action was taken with the assistance of Dr. G. W. Child, the Medical Officer of Health for the Banbury (Oxon) Combined Sanitary District, in which district the farm described in the preliminary Report is situated, and with Mr. Hope, V.C., one of the

directors of the implicated dairy. The preliminary inquiry had made it certain that the milk of six out of the seven farms supplying the dairy was, at the time of the outbreak, free from any suspicion of infection with enteric fever material. But with regard to the milk from the seventh farm the result was very different. Here a condition of things was found which rendered it highly probable that milk from this farm had been charged with enteric fever material, and not improbably with the excremental discharges of a patient suffering from enteric fever, shortly before and during the earlier period of the outbreak in Marylebone. *From this farm was obtained all the milk specially supplied by the implicated dairy for nursery use, the consumption of which milk, as has already been shown, furnishes the strongest evidence of the infection of the milk.*

The farm in question is situated between the villages of Brill and Chilton, in Buckinghamshire, about a mile distant from each, and a foot-path connecting the two villages traverses the farm premises. The farm obtains its labour from both villages. Brill has a population of 1,353, and Chilton of 336, and from each village enteric fever is rarely long absent. During the 14 months ending the 31st August, 1873, there had been, according to Dr. Gent, of Brill (the dates not given), 14 indigenous cases of enteric fever in the village of Brill, occurring in six families, and two imported cases, one of them coming from Oxford, the other from London; the latter being one of the cases of the outbreak in west London under consideration. During the months of June and July 1873 there were under the observation of Mr. M. H. Humphreys, of Thame, nine cases of enteric fever, occurring in five families, in the village of Chilton. One of these cases was attacked whilst working on the farm in question during the third week of haymaking, which began on the 21st June and lasted four weeks. The inquiry as to the relations of cases in the neighbouring villages and hamlets, and of the families in which cases occurred, with the farm was interrupted at this point.

On the 8th June the occupier of the farm died suddenly in the fourth week of an attack of ambulant enteric fever (*Typhus ambulatorius*). For some time previous to the seizure it had been suspected that he suffered from some disease of the heart. The suddenness of the death at a time when it was believed by his medical attendant that recovery from the enteric fever had commenced, led to the death being ascribed to the presumed heart disease, and to its having been certified as occasioned by this cause, no mention being made in the certificate of the disease from which he was considered to be recovering at the time of death.

The history of the case is as follows:—Illness had commenced on the 12th May; but although constantly ailing, the patient did not, in spite of the remonstrances of his medical attendant, Mr. M. H. Humphreys, of Thame, take to his bed until the 1st June. Mr. Humphreys quickly came to the conclusion that the anomalous symptoms from which his patient suffered most probably arose from "latent" enteric fever, a form of the affection frequently seen in the district where the farm is situated. This opinion was confirmed by Dr. Giles, of Oxford, on the 30th May, the patient, against the advice of Mr. Humphreys, insisting upon travelling to Oxford from Chilton, by way of Thame, a distance of about 20 miles. When seen by Dr. Giles, the characteristic eruption of the disease was present. On the second day following (the 1st June) the patient had profuse hæmorrhage from the bowels, which brought about a state of prostration that continued, notwithstanding the abatement of some of the graver symptoms, until the sudden death on the 8th June. The hæmorrhage persisted, with

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diarrhœal evacuations, to a greater or less extent throughout the whole of the succeeding day (June 2), and a part of the day following that (June 3), when the bloody discharges ceased. Opium and mineral acids had been administered, and the bowels remained inactive from the 3rd to the 5th June, when a small dose of castor oil was given, which was followed by a natural stool. This resumption of the normal action of the bowels, together with the cessation of the hæmorrhage, induced a belief that the most dangerous period of the illness had passed, and that recovery had commenced; but the feebleness of the patient was still such that the attendants had been strictly enjoined not to raise him or to suffer him to attempt to raise himself to an erect posture. This injunction was disregarded by the patient on the 8th June, and death followed. The history of this case, indeed, is that of well-marked ambulant enteric fever.

Previous to the hæmorrhage there had been no disturbed action of the bowels. After the hæmorrhage Mr. Humphreys gave directions that all discharges from the bowels and bladder should be kept out of the common privy of the farmhouse, and buried somewhere outside the premises. This direction was carefully carried out; and from the first hœmorrhagic stool to the last chamber slops, all the discharges were removed to an ash-heap beyond the precincts of the farm buildings (as will presently be more fully described), and there the evacuations from the bowels were buried and the slops cast. No disinfectant was mixed with either the one or the other before being got rid of; for, on the one hand, it did not seem to be necessary from the place of burial or casting away; and, on the other, it was not advisable to retain upon the premises the great bulk of the evacuations, passed within a brief period, until a disinfectant had been procured.

On the 12th August a son of the above patient, aged 13 years, was seized with enteric fever, and he passed through a slight but well-marked attack.

Of other persons living at or engaged about the farm (11 in number), viz., the wife and daughter of the occupier, and nine daily labourers,* none had enteric fever at this time, neither had the families of such of the labourers as were married, so far as could be ascertained.

The farm premises, which it is necessary now to describe, and of which a plan and certain sections are attached (*see Plan and Sections*), are situated in a slight hollow in the bottom of a valley. The farmhouse and dairy are very old and incommodious, and a new and more commodious house and dairy, built upon a neighbouring hill, were about to be substituted for them. The farm premises generally are not more satisfactory, much of them ramshackle, and all in curious contrast with the care given to the milk when received into the dairy proper by the mistress of the farmhouse. The water for dairy purposes was obtained from a well in the yard adjoining the farmhouse (*see Plan*) which is mainly fed, by an underground conduit, from another well situated at some distance from the farm, to the west, in a meadow. There is but one privy on the premises, the position of which is shown in the plan. It is placed at a higher elevation than the well used for dairy purposes, and is 56 feet distant from its mouth. The drainage of the farm premises consists, first, of a surface drain for the house and churn-house, and an underground drain for the dairy, both of which run near to the dairy well, as we may term the last-named well (*see Plan*), and open into a ditch,

* These labourers used no milk from the farm except occasionally in their coffee, and then only if there were any surplus milk. They drank, moreover, no water from the dairy well, unless exceptionally, and then, as a rule, after it had been boiled, and in the form of coffee.

which carries off the drainage from them into a pond in the field below the farm; and, next, of a surface drain (a simple ditch) which runs from the farmyard and carries off so much of the drainage of the farmyard as may find its way into it to the ditch which receives the drainage from the first-named drains (*see Plan*). The farmyard drain runs across the line of conduit by which the dairy well is fed.

In this place it may be noted, as an incidental matter, that the live-stock of the farm at the time of the inquiry consisted of about 40 cattle, in excellent condition and health.

At the outset of the inquiry, there was reason to suspect that the dairy well might have become polluted with excremental matters. The position of the well was such, in the bottom of a shallow funnel as it were, that, notwithstanding the surrounding soil was a stiff clay, this had been so much broken up in different directions, as to render soakage either from the privy, the drains, or the pigsty not improbable. The water from the well had for some time been disused in the farm for drinking and cooking purposes, on account of a gradually increasing distastefulness, and for these purposes water was obtained from a spring on the hillside east of the farmhouse, at about a sixth of a mile or more distance. In the rare instances when the dairy well water, from the want of spring water at the moment, may have been lately used, it has probably been without exception for the making of tea or coffee. The increasing distastefulness of the dairy well water, which had led to its disuse for other than dairy purposes, arose certainly from two, and probably from three sources. First, the well in the meadow from which the dairy-well water was mainly fed, was polluted by the stalings and dung of cattle. This well is 11 feet deep by 5 feet in diameter, and is steined with rough unmortared stones. Over the mouth a few loose planks are placed, and wooden rails fence it off from the field. Around these rails the ground is much broken up by the treading of cattle, which appear to court the vicinity of the well when turned to graze in the field. Other more offensive evidences of their partiality for the vicinity of the well are to be observed, and no doubt explain the results of chemical analysis as given below.* Next, where the conduit from

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* "*Report on a sample of water received September* 4, 1873.—Water contained in two Winchester quarts; stoppers tied over; each bottle labelled 'Chilton Grove Farm Well, in the Home Ground, August 30, 1873.'

"The water is slightly turbid, of yellowish-brown colour, and slightly musty odour. It is rather hard, but becomes tolerably soft on boiling. It holds an excessive amount of salts in solution, the greater part of which consist of the sulphates and chlorides of sodium and potassium. The amount of nitric acid present is not great, but there is an excessive amount of ammonia, and the proportion of nitrogenized organic matter present is also rather high, both indicating considerable contamination by sewage or surface drainage. The large amount of chlorine, the very strong trace of phosphoric acid, and the quantity of oxygen absorbed from permanganate, point also strongly in the same direction.

"The analytical details are given in the Table annexed:—

"Appearance		Turbid.
Colour		Yellowish-brown.
Smell		Musty.
Deposit		Slight.
Nitrous acid		Very minute trace.
Phosphoric acid		Very strong trace.
Hardness, before boiling		22 degrees.
„ after boiling		4·6 „
Oxygen absorbed from permanganate		0·1008 grains per gallon.
Total dry residue		114·38 „
Consisting of	Volatile matters	10·36 „
	Fixed salts	104·02 „

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this well to the dairy well passes by the entrance to the farmyard, in which part of its course it lies nearest the surface, the ground is much broken up by the treading of the cattle coming out of and passing into the yard. The ground here is apt to crack deeply in dry weather, and it is not improbable that at such times, if not at all times, farmyard drainage may find its way into the dairy well. The third source of pollution, which touches immediately the subject of the present report, was discovered by Mr. Hope.

A series of carefully executed excavations were carried out under the supervision of Mr. Hope, one of ourselves and the manager of the implicated dairy being also present, to determine whether soakage from the privy and from the drains of the farmhouse could find its way into the dairy well. A previous examination of the interior of the well, the water having been pumped out for the purpose as low as practicable, disclosed a well-marked line of soakage through the interstices of the brick steining on the south side of the well, 3 feet 6 inches above the inlet of the drain from the feeding well, and 9 feet from the surface. Other more doubtful points of soakage existed, which need not be described.

The position of the trenches dug in the excavations made are shown by dotted lines on the Plan. These excavations proved conclusively, (1) that no soakage was possible from the privy into the dairy well; (2) that no soakage had taken place either from the surface yard

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Chlorine - - - - - -	5·46 grains per gallon.
Nitric acid (N_2O_5) - - - -	0·68 „
Nitrogen in ammonia - - - -	0·073 „
Organic nitrogen - - - -	0·025 „

"(Signed) A. DUPRÉ.

"Westminster Hospital, September 9, 1873."

A copy of analysis of water from the "Dairy Well" is subjoined.

"*Report on a sample of water received August* 14, 1873.—Sample contained in two Winchester quarts; stoppers tied over; each bottle labelled, 13th August, 1873. Pump, Chilton Grove, used for cleansing milk cans and for dairy purposes.

"N.B. Well-mouth opened half an hour before specimen taken, and a portion of earth and mortar fell in.

"The water is turbid, of yellowish-brown colour and without odour. It is extremely hard, and holds an excessive amount of salts in solution, consisting in great part of the chlorides and sulphates of sodium and potassium. There is not much nitric acid, but ammonia and nitrogenized organic matter are present in rather high proportion. A considerable amount of chlorine is also present, and much oxygen is absorbed from permanganate. In fact, the water shows all the characteristics of recent contamination by sewage or surface drainage.

"The analytical details are given in the Table annexed:—

"Appearance - - - - -	Turbid.
Colour - - - - - -	Yellowish-brown.
Smell - - - - - -	Inodorous.
Deposit - - - - - -	Slight.
Nitrous acid - - - - -	None.
Phosphoric acid - - - -	Very strong trace.
Hardness, before boiling - - -	36 degrees.
„ after boiling - - -	17 „
Oxygen absorbed from permanganate -	0·112 grains per gallon.
Total dry residue - - -	121·66 „
Consisting of { Volatile matters -	11·48 „
Consisting of { Fixed salts - -	110·18 „
Chlorine - - - - - -	7·315 „
Nitric acid (N_2O_5) - - - -	0·370 „
Nitrogen in ammonia - - - -	0·0147 „
Organic nitrogen - - - -	0·0273 „

"(Signed) A. DUPRÉ.

"Westminster Hospital, August 18, 1873."

drain or from the dairy drain into the well; and (3) that no soakage from the farmyard drain, or the farmyard, or elsewhere had passed along the upper part of the trench in which the conduit from the well in the meadow to the dairy well was laid. These questions having been successfully put aside, a trench was run up to the yard wall, from the garden plot on the south side, a little to the east of the position of the well, and on digging beneath the foundation of this wall unquestionable signs of soakage of some foul matter were found. On this being discovered, an excavation was made between the well and the yard wall, and a line of soakage disclosed along the foundation of the wall, through the made earth intervening between the wall and the well, to the point where soakage had been discovered in the well.

The reason of the growing foulness of the water from this well, which had caused its disuse some time before for drinking and cooking, now became at once obvious. The soakage could only come from one direction, that of the pigsty. The yard wall and the southern wall of the pigsty and their foundations were continuous. The drainage of the pigsty flowed to the south side of the wall, and there accumulated. (*See* Plan.) The surface drainage from the yard was also occasionally dammed up against the wall, as one of us at the time of the first inspection of the premises had occasion to see. Now there can be no reasonaable doubt, from the result of the excavations, that the drainage of the pigsties and of the yard had, in the progress of time, made its way along the foundation of the wall, a distance of about 25 feet, to the vicinity of the well, and then soaked through the intervening soil into the well. The latter process, from the nature of the soil, would be a slow one, but it had been accomplished so effectually that the clay which constituted the bulk of the made ground between the wall and the well, was, along the line of soakage, reduced to the consistence of very soft paste.

Against the wall along the foundation of which this soakage takes place, and close to the pool formed by the drainage from the pigsty, is the ash heap of the farm. In this ash heap were buried all the evacuations from the bowels of the sick occupier of the farm on the 1st, 2nd, and 3rd of June, and upon it were cast all the chamber slops of the sick man's room from the 1st to the 8th June. *In other words, by an unhappy and altogether unforeseen chance, and in carrying out precautions to obviate any possibility of mischief the matters from which mischief was most apt to arise were deposited in perhaps the only spot on the farm premises where they would certainly find their way into the water used for dairy purposes.*

There is probably no etiological truth more clearly established than that of the propagation of enteric fever by water contaminated by the discharges of persons ill of the disease. The next step of the inquiry was then directed to ascertain whether such ordinary use was made of the dairy well water as would probably lead to its being mingled with the milk in proportion sufficient to cause the outbreak. It will be observed how completely such an assumption would meet the known phenomena of the disease and of the outbreak. The outbreak began in the week ending July 5, that is to say, during the last days of June and the first days of July; consequently, the cause determining the outbreak must have begun to operate sometime during the week ending the 21st June. The dropping cases of the first three weeks of the outbreak were followed by the great outburst extending over three weeks and then by a decline, sudden at first, but occupying three weeks

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following. These phenomena might not unreasonably be held to have reference to the physical phenomena of soakage of the infective matters into the well, slowly and in small quantities at first, rapidly increasing in amount as the infective matters occupied more fully the line of soakage, and as rapidly declining, but still not at once, and wholly coming to an end, as those matters became exhausted. Given a fortnight for the soakage to begin to affect the water, a not undue period having regard to the kind of soil it would have to pass through in a part of its course, the rest of the phenomena would consistently explain the outbreak provided the contaminated water were mingled with the milk. It is not unimportant to observe, in respect to this soakage, that it would take place under conditions reducing the destructive changes among the infective matters which otherwise might have been facilitated by the soil to a minimum, for the whole line of soakage was previously sodden with moisture, a condition which largely deprives earth of its peculiar action upon excremental matters.*

For practical purposes, and apart from all theoretical considerations, it was sufficient to know that the only water used for all dairy purposes upon the farm was a water liable to be contaminated, and which was at a particular period, in all probability actually contaminated, in the exceptional mode described. This water was, for the purpose of cleansing the dairy utensils, as a rule used cold, and simply as taken from the well. In cleansing the churns, for example, these were rinsed with the water before each time of use, and then wiped inside and out with cloths. The necessary frequent scalding of the churns with boiling water was not, except at long intervals, carried out at the farm, but at the dairy in London to which they were consigned. Of any actual mingling of the well-water with the milk, other than might arise from imperfect drying or draining of the interiors of the churns after rinsing, no evidence was obtained, nor, indeed, can be expected at any time, in such inquiries, except by accident. But no accidental pollution would explain the limitation of the infection to "nursery-milk," or the persistence of this infection for a definite time.

6. The conclusions, however, as to the infection of the milk, and of the probable connexion of the infection with this particular farm, rest upon evidence entirely apart from that which relates to the mode of infection of the milk. It must be remembered that the failure to show in what manner this infection may have happened, does not in the least militate against the evidence of infection. This latter evidence, as well as that relating to the source of infection on a particular farm, can be dealt with separately from the question of the mode in which the infection may have come about. It is necessary to insist upon this point, because there is a tendency to make the two former questions depend upon the solution of the latter. Now, although it is most

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* We have been favoured by the Rev. Robert Main, M.A., F.R.S., of the Radcliffe Observatory, Oxford, with a Table (*see* Appendix, Table II.) showing the mean daily readings of the barometer and thermometer, and the amount of rainfall, day by day, at the Radcliffe Observatory, during the months of June and July 1873. Chilton Grove Farm is situated 10 miles, in a direct line, from Oxford, in a valley among the hills on the Buckinghamshire border. The states of temperature, and perhaps even of rainfall, at Oxford will probably in their general features indicate pretty closely the states at Chilton Grove Farm. The high, and on some days excessive temperature shown by the Table to have existed with little interruption from the 16th to the 29th June, is suggestive in connexion with the starting activity of infection from the farm. The heavy rainfall on the 29th June (probably more prolonged among the hills) is also suggestive, as such rainfall would facilitate a more rapid passage of infective matters into the dairy well.

desirable that the method of infection should in all cases be, if possible, determined, the question is one presenting difficulties for solution which, as a rule, will probably prove insuperable. For not only do these difficulties beset the inquiry as to the ordinary intimate habits of a farm, but they are always complicated with the possibility of the milk having been tampered with without any knowledge of the farmer, and within such limits as to render the methods of testing usually employed in dairies quite unavailable for detection.

For the ultimate purpose of this inquiry, it is sufficient to have shown a probability amounting, for practical purposes, to a certainty that—

(1.) The outbreak of enteric fever which forms the subject of inquiry, was caused by milk infected with enteric fever material;

(2.) That this milk came from a particular farm;

(3.) That the water used for dairy purposes on this farm contained excremental matters from a patient suffering from enteric fever immediately before and at the time of the outbreak.

Preventive action, to be of any value, must follow upon the reasonable probabilities of a case such as this outbreak, and not wait upon a minute etiological elaboration. The course to be taken, and which was followed, was clearly obvious at the time of the preliminary inquiry, and the justness of that course is, we think, confirmed by the detailed investigation. The implicated dairy at once stopped the supply of milk from the farm; and the mistress of the farm (the widow of the late occupier), although acting against her own convictions, with a decision which did her infinite credit, immediately stopped all issue of milk from her farm, and gave up the use of the dairy-well. Dr. Whitmore first received information of the outbreak, and of its probable cause, on the 4th of August. On the 8th he had become aware that the event involved issues which extended beyond his own district, and he took those measures which made it possible to push the preliminary inquiry quickly to its end, and to stop the supply of suspected milk on the 12th.

It will rarely happen that the source of an outbreak of the kind under consideration will be so readily traced and rapidly followed out as in the present instance. But, notwithstanding the quickness of detection, and the ready action taken upon it, the detailed inquiry, of which the results are given here, we think, tends to prove *that the infection of the milk had probably ceased before the discovery of the source of the outbreak*, that is to say, before the 4th of August.* No evidence has come to our knowledge of any case certainly connected with the milk after the 12th August. It would follow, therefore, that, if any effective action is to be taken for the prevention of outbreaks of enteric fever from infected milk, this action must be directed to the removal of possible sources of infection. In the present instance, and in other instances, the milk probably became infected from the water used for dairy purposes having been previously infected. Some instances are on record in which it would seem probable that the milk had become infected by being placed in such relations with the sick, or

* One case was reported to us in which milk was stated to have been drunk, once and once only, at the dairy on the 8th or 9th of August, and in which the individual sickened of enteric fever at a period variously stated from three to six days afterwards. As it was impossible to exclude other probable sources of infection in this case, we have not included it in the series connected with the milk supply.

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the sick chamber, as to absorb, or in some other way become contaminated with the enteric fever material. In both kinds of instances the question of prevention becomes a part of a more general question touching the regulation of dairy farms.

7. And first, in respect to the water supply of these farms, the probable medium of infection of the milk in the outbreak under consideration. The water supply of several of the dairy farms which came under observation in the course of the inquiry, not only the farms supplying the implicated dairy in the metropolis, but also others, was either exceedingly impure, or was exposed to chances of contamination similar in kind to that described in this Report. The following examples may be given in illustration :—

A considerable and otherwise excellently-ordered dairy-farm : the well of the farm, partly supplied by percolation, but chiefly by collection of surface water, which passes from a large pond into the well along a deep trench arranged as a filter. Thirteen feet from this trench, and 30 feet from the mouth of the well, is a capacious privy-pit, lined with brickwork and cemented. This privy-pit is emptied only at long intervals. Soakage from the privy-pit into the well is held to be impossible ; first on account of the construction of the pit, and next, on account of the soil intervening between the privy-pit, and the well being clay. There is no assurance that these reasons are valid, because cemented brickwork is not a sure safeguard against soakage of excremental matter, and it is not certain that the soil lying between the privy-pit and the well has not been disturbed. The surface water also is apt to be polluted from manure spread on the land, from which it is obtained. In addition to the chance of excremental pollution of the well from these sources, a pond, from which an occasional supply of water is obtained, is exposed to excremental pollution, a privy-pit being built on the edge of it. An examination of the water from this well, made on the 29th August, showed that it had then a most unpleasant odour, and an analysis of a specimen collected that day gave results which could leave no doubt that it was laden with excremental matters, brute or human, or both.* Water of the degree of impurity indicated by the analysis given below is certainly not fitted for dairy purposes any more than for household purposes. If, as we believe

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* " *Report on a sample of water received September* 4, 1873, and collected August 29, 1873 :—

" The water is very turbid, has an offensive smell, and contains much ammonia and nitrogenized organic matters. It is a very bad water.

" Appearance		Very turbid.
Colour		Brownish-yellow.
Smell		Slightly putrid.
Deposit		Much brown, flocculent.
Nitrous acid		None.
Phosphoric acid		Much.
Hardness, total		22 degrees.
„ after boiling		5·5 „
Oxygen absorbed from permanganate		0·314 grains per gallon.
Total dry residue		46·48 „
Consisting of	Volatile matters	6·38 „
	Fixed salts	40·10 „
Chlorine		5·81 „
Nitric acid (N_2O_5)		0·11 „
Nitrogen in ammonia		0·045 „
Organic Nitrogen		0·063 „

" (Signed) A. Dupré.

" Westminster Hospital, September 17, 1873."

probable, the excremental pollution partly arises from soakage from the privy-pit, the water in the well may at any moment become infected, either as a direct consequence of that pollution, under conditions as yet undetermined, or from the discharges of a person suffering from enteric fever finding their way into the privy-pit, and thence into the well. Should this happen, there is no surety that the milk would not be infected through the water, and become the medium of an outbreak of enteric fever of much greater magnitude than the one described in this report.

The imminence of this kind of danger was strikingly illustrated during the inquiry by an example brought under observation by Dr. Child, the Medical Officer of Health for the district, and which formed the subject of a conjoint inspection. The occupier of a large dairy farm had died, after a few hours' illness, with severe choleraic symptoms. All the earlier copious alvine evacuations of the patient had been passed into the privy of the farmhouse. This privy was situated 30 feet from the mouth of the well which supplies the house and dairy with water. Both the privy-pit and the well are hollowed out of an outlier of pervious and fissured corn-brash, upon which the farmhouse and neighbouring village are built. The privy-pit is emptied at yearly or longer intervals, more frequent cleansing not being necessary from the facility with which the liquid contents pass away into the soil. At the time when the occupier was first seized with his fatal illness there was a momentary doubt whether the disease was not Asiatic cholera, for the seizure happened at a time when that disease was spreading on the Continent, and scattered cases had been introduced into England. If the attack had proved to have been one of Asiatic cholera, it is not pleasant to contemplate the consequences which might have taken place had the discharges found their way, as they probably did do, into the well. It is hardly more agreeable to contemplate the possible consequences of ordinary choleraic discharges obtaining access to water used for dairy purposes. The chances of mischief arising from this dairy farm at this time were perhaps diminished by the milk being mainly used for butter making.

In the same dairy farm was also observed the extraordinary arrangement of the washhouse communicating with the dairy. At the time of inspection the washing of house-linen was in progress, and upon one of the slabs in the dairy was piled up a quantity of rough-dried linen, body and other. It is impossible to set a limit to the chances of infection under arrangements of this kind, if a contagious disease should be present in the house.

The foregoing examples are taken from first-class dairy farms, and no good will arise from multiplying illustrations from lower grade farms, where like conditions exist in a greater or less degree. Two examples may be given, however, illustrating from another point of view the curious indifference which exists among farmers to the quality of the water-supply used for dairy purposes.

The first instance refers to a very old farmhouse, the water-supply of which is obtained from a running stream. A conduit from this stream brings the water for domestic and dairy purposes to a catch-pit, and is separated from the cattle yard by a simple brick walling and a thin layer of soil. The yard is deep in the accumulated bestial filth of years, and the soil and adjacent wall-foundations are super-saturated with the soakage from the filth above. A simple inspection of the catch-pit shows that it must be within the limits of soakage. Lower down the stream from which the conduit supplying this catch-pit takes its depar-

ture, the current is dammed, and here is arranged the cooling place for the freshly-filled milk churns. Suspended from a branch of an overhanging tree, the churns rest in the bright, flowing stream. The arrangement for its efficiency might well excite the envy of less-favoured dairy farmers. And, indeed, when seen in a glowing sunset, the arrangement formed the centre of a bit of rustic scenery delightful to the eye, for the stream at this spot was overshadowed by abundant foliage. But amidst this foliage, a few yards above the suspended churn, up stream, was discovered, fixed across the running water, the common privy of the farmhouse!

Again, a spring was visited from which it was contemplated, in the event of a sufficiency of water not being found by sinking a well on the premises, to supply a new and handsome farmhouse and dairy. This spring flows from a hill-side beneath a clump of hawthorns, and forms a picture which would please an artist, if he had the courage to get at it. The water is conducted first into a trough for the use of cattle, and the overflow passes in two directions. In the one it is led to a roughly made reservoir, in the other to a small trough for the use of a cottage, and the overflow from this latter trough passes still lower down the hill-side to another cattle-trough. So ill tended are all these arrangements, that on the slope above the spring, and around the two cattle-troughs, the ground is trodden into almost impassable sloughs by the cattle, and the water, even from the outlet of the spring, is indescribably fouled by their stalings and dung. The water in the cottage trough had a distinct brown colour, and the water in the lower cattle-trough was, in addition to the fouling at its source, exposed also to pollution from the drainage of a pigsty placed on the bank above. *Water from the uppermost trough—from the springhead, in fact—in the state in which one of us saw it had been used for dairy purposes.*

Until this habitude of using, and indifference to the use of, foul water, or of water liable to be fouled, for dairy purposes is put a check to, probably the most important source of infection of milk with enteric fever material will hardly be removed. Such infection is, indeed, to be held as one of several highly probable evils arising from this source. One of the results of this inquiry which has been most forcibly impressed upon the reporters is that the use of water for dairy purposes fouled after fashions such as have been described may, by inducing changes in the milk, particularly under high ranges of temperature, play an influential part in determining fatal infantile diarrhœa.

Aided by the growing feeling among farmers themselves of the indecency and impropriety of using impure water for dairy purposes, it ought not to be very difficult to put a stop to the evils of the kind discussed in this Report. The main obstacles, perhaps, in the way of improvement hitherto have been mistaken estimates of the mischief arising from these evils, and of the cost involved in carrying out the necessary changes to remove them.

If the descriptions given in this Report have not failed of their object, a brief consideration of them should show that the alterations required in the different farms to abate or prevent the pollution of their water-supply are of the simplest and least expensive kind. Take the farm in which the subject of the present inquiry has been centred, the work would be both easy and little costly to make the feeding-well in the meadow free from all chance of pollution from the surface washings and soakage. Means as simple and little costly could be devised to carry this water to the farmhouse, and there store it beyond the practicability of pollution except from wilfulness or carelessness. In the

second farm described, where the question of water-supply is one of no little difficulty, the removal of the privy-pit and of the earth intermediate between it and the well, substituting fresh earth, also the removal of the privy-pit from the edge of the pond which furnishes an occasional supply, would obviate probably the only serious danger to the water-supply. Such impurity as finds its way into the collected surface water ordinarily used should be dealt with by a more effectual filtration. In a neighbouring farm, where the occupier had some reason to suspect that the well might be affected by the privy-pit, this had been filled up and the danger entirely removed by the adoption of a pail-closet. In the third farm described, the filling-up of the privy-pit, the adoption of a pail-closet, and, in addition, the removal of a piggery, placed too near the well, to another part of the farm, would save the well. Of the other instances given, the proper manner of dealing with them, and the simplicity of the requirements, must be obvious. No instance has been observed during this inquiry in which possible or actual pollution of the water-supply has not arisen from the failure to observe common sense rules in the arrangements for collecting the water, for excrement disposal, or for drainage, and in which the evil results thus arising could not readily be remedied.

It is not probable, however, that the improvements indicated above, in the regulation of dairy farms, will be carried out either so quickly or so completely as is to be desired in the interest of milk consumers, if they are left to the sole action of farmers and milk dealers. The proprietors of the implicated dairy had not been unmindful of the sanitary condition of the farms from which they obtained their supply, and they had endeavoured to secure the rectification of such evils as might affect the purity of the milk. But their efforts were practically futile, except in so far as they referred to the manipulation of the milk and the condition of its delivery. This, we apprehend, must be the customary result as regards the matters immediately under consideration until the Local Sanitary Authorities interfere. We believe such interference to be necessary for the proper regulation of dairy farms, and to this end the Sanitary Authority should be possessed of a thorough knowledge (obtained through its medical officer of health) of the dairy farms within its district, in respect of the different matters referred to. The powers of inspection which a sanitary authority now possesses, and its ability to deal with certain defects of privies and drainage would, judiciously exercised, meet some of the evils described; but, having regard to the very serious dangers to which milk consumers are exposed from them, it would appear to be desirable that any further powers which may be requisite for carrying out such inspections successfully should be granted, and that the authorities should possess the power of closing polluted sources of water supply in case of necessity.

The proprietors of the dairy through which the infected milk was distributed in London, during the outbreak which forms the subject of this Report, have, since the outbreak, adopted, in addition to previous precautions, an elaborate system of inspection, medical and veterinary, on the farms supplying their dairy, and are again endeavouring to bring about upon them all necessary sanitary improvements. It is most improbable, however, that such private measures will become general, or, if general, successful; and already it has been discovered that in some dairy farms much-needed improvements in the interest of milk consumers will not be carried out unless the law interferes.

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APPENDIX.

Mr. J. Netten Radcliffe's Preliminary Report on the present prevalence of Enteric Fever in Marylebone and adjoining Metropolitan Districts.

In accordance with instructions received on the evening of Friday the 8th instant, I proceeded at once to make an investigation of the facts communicated to the Department respecting the prevalence of typhoid in Marylebone, and the reported connexion of this prevalence with the distribution of milk from a particular dairy; and having satisfied myself that there were sufficient grounds for suspecting that the disease might have been disseminated through the medium of milk, early the next morning I placed myself in communication with Dr. Whitmore, the Medical Officer of Health for Marylebone, and at 10 a.m., in company with him, I had an interview with the directors of the suspected dairy. Dr. Whitmore had already been in communication with the directors on the subject, and they had sought the advice of Professor Corfield. The last-named gentleman was present at the meeting, and I had the advantage of his co-operation, as well as that of Dr. Whitmore, in the subsequent proceedings. The directors, without reserve, offered every facility for pursuing the investigation with which I was charged, and although unconvinced by the evidence which had to that time been laid before them as to a probable relationship between the prevalence of typhoid in Marylebone and the distribution of milk from their dairy, they immediately assented to the suggestion made by Dr. Whitmore and myself, and supported by Dr. Corfield, that the different farms from which they obtained their supplies should be inspected.

This inspection could not be carried out earlier than the Monday following; and in the course of Saturday and Sunday I was able to obtain information relating to numerous cases of enteric fever which had occurred in 28 households living in Wimpole Street, Queen Anne Street, Mansfield Street, Nottingham Place, Green Street, South Audley Street, Portman Square, Seymour Street, and St. John's Wood. This information made it probable that the cause of the coutbreak of enteric fever in the streets in question was the distribution of milk contaminated with the poison of the disease. Reserving details for a later report, it is sufficient for my purpose here to state that—

(*a.*) The cases had almost all occurred in the month of July, and the greater number of them in the course of a single week.

(*b.*) I had the assurance from the Medical Officer of Health for the Marylebone district, Dr. Whitmore, that the sewerage of the localities in his district, where enteric fever was most prevalent, was in thorough order, that it had long been so, and that the distribution of the fever was not according to any particular line of sewers.

(*c.*) The cases were distributed in the area of two several water companies, in a manner that appeared to negative the supposition that the general water supply could be at fault, or that there could have been contamination of a particular local branch of supply.

(*d.*) In the cases which had been most completely observed, the chances that the disease had been contracted outside the patient's house, or that it in any way depended upon sanitary defects of the house, could be almost absolutely excluded.

(*e.*) The above circumstances being taken into account, and the various known means of fever-dissemination being reviewed, the way that suggested itself as being here the most probable was distribution of the material of the disease with some article of food.

(*f.*) There were several important facts which seemed to point directly to milk as this sourse of dissemination :—

(1.) Of the 28 households, 26 obtained their supply of milk from the same dairy.

(2.) The number of children affected was proportionately very great.

(3.) In the instance of adults affected, large use of milk was a notable fact.

(4.) In the infected streets the disease picked out as it were the houses supplied from the particular dairy.

(5.) In particular families, in more than one instance, the disease picked out the members who drank the suspected milk, and those only.*

The results of this preliminary investigation made it imperative that the farms from which the suspected dairy derived its milk should be inspected without delay, and on Monday, accompanied by Dr. Whitmore, Dr. Corfield, and also by Mr. J. Chalmers Morton, who had been requested by the directors of the suspected dairy to assist in the inquiry, I proceeded to Oxford for the purpose.

A list of all the farms from which the suspected dairy had been recently supplied with milk was prepared for me. An examination, which I had made on Sunday morning, of the mode of dealing with and distributing the milk from the suspected dairy in London, satisfied me that the implication of a single farm would go far to explain, if it did not wholly explain, the phenomena of the outbreak in London. The farms were seven in number, two of them being situated near Oxford, the remainder in the vicinity of Thame. An examination of the reports of tne Registrar General for the first and second quarters of the year showed that three of the farms were situated in a sub-district which must have been the scene of a serious outbreak of enteric fever extending over the two quarters.

The whole of the farms were carefully inspected by me and the gentlemen associated with me in the course of Tuesday and Wednesday, but before the close of Tuesday the evidence became so strong that at a particular farm there had been opportunities of fever infection, that it was decided to telegraph to the dairy in London to suspend immediately the issue of milk from this farm, and Dr. Corfield telegraphed to this effect. I have since my return to town ascertained that this telegram was acted upon, and that from that time the issue of milk from the farm in question ceased. I may add that all supplies from this farm are now stopped.

On Wednesday morning, before which period we were not able to visit the suspected farm, we made a detailed inspection thereat, by which the course taken the night before was fully justified. Of all the farms inspected, in this alone had we found any reason to believe that milk contaminated with enteric fever poison might have been issued during the period over which the inquiry extended. In the farm now under consideration we found the following state of things:—

(*a*.) The water supply of the farm used for dairy purposes was manifestly polluted—so manifestly as to prevent its being used ordinarily for drinking purposes in the farmhouse—and there was good reason to believe that this pollution might be in part excremental.

(*b*.) The proprietor of the farm had, a few weeks before the outbreak, been the subject of enteric fever, from which he was recovering, when, on the 8th June, he died suddenly of heart disease.

(*c*.) The labourers working on the farm, nine in number, came from the villages of Brill and Chilton, both villages much infected for some time with enteric fever, although it was not known that any of the labourers had themselves suffered from the disease.

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* In the subsequent investigation the instances to which this statement referred proved to be cases in which members of the family had been accustomed to take the milk largely in its natural state, as compared with other members who only used it with coffee or tea.—J. N. R.

(*d.*) The mode of carrying on the dairy work was such that, given the infection of enteric fever on the premises, more than one mode could be suggested in which the poison of the disease might be conveyed into the milk.

(*e.*) The time of the farmer's illness from enteric fever was, in conjunction with the state of things found on the farm, quite reconcilable with its being the source of the outbreak of enteric fever in Marylebone, &c.

A review of the whole circumstances of the inspection led me to the conclusion that the outbreak of enteric fever in Marylebone and neighbouring districts, which was the subject of my inquiry, had most probably its origin in the distribution from this farm of milk contaminated with the poison of this disease.

I have the gratification of stating, that on this conclusion being notified to the manager of the farm—the widow of the lately deceased farmer—she, notwithstanding the difficulty she felt in admitting its correctness, at once said that she would stop the issue of milk, upon her own responsibility, for the time being.

I have now reported, briefly, the action I have taken in this investigation to the present time. In continuing it, it will be necessary on the one hand to make a complete inquiry into the facts of the outbreak in Marylebone and the neighbouring metropolitan districts, and on the other hand to carefully examine the state of things in respect to enteric fever, which had come under observation in the inspected district about Thame, as well as to inquire into the prevalence of fever in the sub-registration district of Brill, and the possible infection of other farmsteads there. In several of the farms inspected, the possibility of pollution of the milk with enteric fever poison, if enteric fever should show itself in the farm house, or among the labourers working upon it, was obvious, and it seems to me that an inquiry directed to the removal of this danger, may, now that the sanitary organisation of the rural districts is a definite matter, be carried out with some prospect of success.

I propose, therefore, subject to the approval of the medical officer,—

1. To make a detailed investigation of the outbreak of enteric fever in Marylebone and neighbouring districts, for which, having regard to the time which will otherwise be occupied in this inquiry, I must ask for some assistance.*

2. To inspect carefully the Brill sub-registration district and the district about Thame, with special reference to the subject of the prevention of such outbreaks of enteric fever as that which forms the subject of this investigation.

Medical Department of the Local Government Board,
August 15, 1873.

Postscript.—I visited the suspected farm a second time on the 19th instant, when I was accompanied by Dr. G. W. Child, the Medical Officer of Health for the district. We found that no milk had been sent from the farm since the date of my first visit; that the water from the polluted well, previously used for dairy purposes, had been entirely disused, and the pump by which it was obtained, deprived of its piston; that the dairy had also been disused, and that arrangements were almost completed for carrying out the dairy work in future in new buildings at the top of a neighbouring hill, the water for dairy purposes being obtained from a spring at some distance from the house, believed to be quite free from danger of sewage contamination. From the medical attendant at the farm, whom we met there, we learnt that a son of the occupier, who had been indisposed at the time of my first visit, was suffering from well marked enteric fever.

J. N. R.

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* Mr. W. H. Power was, by direction of the Board, associated with me from the date of this Report, in the inquiry.—J. N. R.

App. No. 6.

Enteric Fever in West London, by Mr. Radcliffe and Mr. Power.

TABLE I.—Showing the WEEKLY MORTALITY from "FEVER" and DIARRHŒA in the METROPOLIS, 1873.

Week.	"Fever." Average Mortality 10 Years, 1863–72.	"Fever." Mortality, 1873.	Diarrhœa. Average Mortality, 10 Years, 1863–72.	Diarrhœa. Mortality, 1873.	1873. Means (Greenwich.)* Barometer.	1873. Means (Greenwich.)* Temperature.	1873. Means (Greenwich.)* Rainfall.
							Inches.
1	53·9	25–	13·8	15+	29·58	45·2+	0·80
2	56·1	22–	13·5	13–	29·69	47·9+	0·92
3	55·0	22–	13·5	11–	29·81	46·1+	0·26
4	50·4	25–	12·0	13+	28·98	37·4=	0·62
5	54·8	25–	14·5	13–	29·86	33·3–	0·02
6	48·8	24–	13·3	23+	29·75	32·9–	0·59
7	52·3	27–	14·3	12–	30·07	36·0–	0·04
8	49·6	37–	13·1	18+	30·32	33·4–	0·08
9	47·9	19–	13·8	13–	29·33	36·0–	1·44
10	47·0	18–	13·3	10–	29·58	43·3–	0·24
11	47·4	24–	12·2	25+	29·38	38·6–	0·40
12	45·6	35–	11·6	25+	29·72	39·1–	0·31
13	46·6	34–	14·0	10–	29·86	45·3+	0·01
14	43·0	20–	12·8	18+	29·83	48·6+	0·21
15	46·1	25–	14·2	20+	29·85	41·7–	0·19
16	46·8	29–	15·7	15–	29·59	52·1+	0·06
17	47·8	19–	14·2	10–	29·89	42·5–	0·07
18	40·9	20–	14·0	13–	29·84	48·5–	0·27
19	41·7	25–	14·9	13–	29·55	48·4–	0·90
20	39·5	34–	16·6	12–	29·87	50·1–	0·15
21	39·0	22–	14·5	12–	29·80	49·6–	0·27
22	41·0	22–	20·5	16–	29·96	53·4–	0·17
23	38·8	22–	24·7	17–	29·80	55·4–	0·68
24	40·9	24–	28·5	18–	29·62	56·8–	0·26
25	40·2	16–	55·8	20–	29·89	60·4+	0·67
26	39·1	20–	86·7	22–	29·89	60·2+	0·00
27	41·3	24–	125·9	68–	29·71	61·6+	0·98
28	44·4	20–	159·3	100–	29·79	62·6+	0·49
29	43·3	21–	231·0	205–	29·73	59·1–	1·21
30	41·9	37–	310·5	305–	29·86	68·8+	0·03
31	42·9	22–	313·7	375+	29·86	63·7+	0·27
32	41·8	25–	273·5	470+	29·84	66·0+	0.45
33	44·4	30–	239·9	405+	29·85	63·5+	0·55
34	44·7	32–	213·9	362+	29·68	60·0–	0·65
35	45·8	38–	181·6	277+	29·63	61·9+	1·20
36	47·2	27–	158·9	229+	29·76	56·0–	0·51
37	49·8	26–	127·0	162+	29·62	55·0–	1·10
38	47·3	34–	90·5	127+	29·61	55·0–	0·97
39	47·6	39–	80·1	85+	30·10	54·4–	0·00
40	42·7	43=	59·0	71+	29·84	57·2+	0·00
41	48·4	45–	47·5	48–	29·67	52·0=	0·52
42	48·0	32–	41·2	30–	29·74	48·4–	1·29
43	49·0	55+	31·1	29–	29·38	44·8–	0·71
44	53·8	42–	25·1	21–	29·78	38·9–	0·32
45	50·0	35–	21·5	18–	29·36	44·9–	1·46
46	53·5	47–	19·9	13–	29·92	40·8–	0·29
47	53·7	40–	16·9	12–	29·96	43·3+	0·18
48	56·1	35–	17·1	15–	29·64	48·0+	0·44
49	56·8	41–	14·3	11–	30·28	43·3+	0·00
50	56·2	30–	14·9	9–	30·42	33·6–	0·00
51	53·6	35–	12·4	11–	29·95	45·4+	0·06
52	52·7	28–	12·1	7–	29·94	42·9+	0·17
53	52·7	31–	12·1	12–	29·71	39·0+	0·33

N.B.—The signs + and – simply indicate, of the figures to which they are attached, above or below the average without reference to the amount of excess or diminution.

* Records of observations, made in the Royal Botanic Society's Garden in Regent's Park, prior to and during the period of the outbreak, have also been examined; and the result of these observations is to show a practical identity of meteorological conditions at Greenwich and in Marylebone.

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Enteric Fever in West London, by Mr. Radcliffe and Mr. Power.

Table II.—Mean Daily Readings of the Barometer, and Mean Daily Temperature, with the Rainfall day-by-day at the Radcliffe Observatory, Oxford, for the Months of June and July 1873, and the Differences of the Barometer and Thermometer from the Monthly Mean of Five previous Years.

Date.	Barometer reduced to 32°.	Excess.	Mean Temperature.	Excess	Rain.	Date.	Barometer reduced to 32°.	Excess.	Mean Temperature.	Excess	Rain
1873.	Inches.	Inches.	°	°	Ins.	1873.	Inches.	Inches.	°	°	Ins.
June 1	29·814	−0·004	51·5	−7·0	—	July 1	29·812	+0·048	61·8	−2·0	—
2	29·734	−0·083	53·6	−4·9	0·149	2	29·748	−0·016	62·1	−1·7	0·004
3	29·628	−0·189	58·7	+0·2	—	3	29·546	−0·218	62·1	−1·7	0·007
4	29·618	−0·201	60·2	+1·7	0·649	4	29·575	−0·189	57·4	−6·4	0·215
5	29·724	−0·093	56·3	−2·2	—	5	29·568	−0·198	59·5	−4·3	0·035
6	29·966	+0·149	51·9	−6·6	—	6	29·806	+0·042	60·1	−2·7	—
7	30·022	+0·205	54·4	−4·1	—	7	29·869	+0·105	64·5	+0·7	—
8	29·923	+0·106	58·0	−0·5	—	8	29·874	+0·110	65·7	+1·9	—
9	29·632	−0·185	57·3	−1·2	—	9	29·797	+0·033	62·2	−1·6	0·004
10	29·480	−0·337	57·3	−1·2	0·020	10	29·654	−0·110	61·2	+2·6	—
11	29·397	−0·420	56·6	−1·9	—	11	29·570	−0·194	60·1	−2·7	—
12	29·339	−0·478	58·0	−0·5	0·020	12	29·461	−0·303	57·8	−6·0	0·220
13	29·493	−0·324	54·3	−4·2	0·510	13	29·349	−0·415	56·1	−7·7	0·900
14	29·564	−0·253	56·8	−1·7	0·023	14	29·488	−0·276	55·2	−8·6	0·360
15	29·666	−0·151	57·4	−1·1	—	15	29·688	−0·076	58·4	−5·4	0·035
16	29·763	−0·054	58·8	+0·3	—	16	29·884	+0·120	61·5	−2·3	—
17	29·766	−0·051	59·8	+1·3	0·044	17	29·748	−0·016	63·2	−0·6	0·053
18	29·836	+0·019	61·5	+3·0	—	18	29·835	+0·071	58·2	−5·6	—
19	29·911	+0·094	58·1	−0·4	0·010	19	29·940	+0·176	61·1	−2·7	—
20	30·006	+0·189	63·3	+4·8	—	20	29·947	+0·183	67·6	+3·8	—
21	29·964	+0·147	66·2	+7·7	—	21	29·850	+0·086	75·2	+11·4	—
22	29·828	+0·009	62·4	+3·9	—	22	29·715	−0·049	72·8	+9·0	0·053
23	29·822	+0·005	60·3	+1·8	0·028	23	29·781	+0·017	65·3	+1·5	—
24	29·684	−0·133	58·0	−0·5	0·018	24	29·795	+0·031	67·4	+3·6	—
25	29·918	+0·101	56·4	−2·1	—	25	29·732	−0·032	64·2	+0·4	0·110
26	29·915	+0·098	60·5	+2·0	—	26	29·729	−0·035	63·3	−0·5	—
27	29·861	+0·044	60·7	+2·2	—	27	29·763	−0·001	61·1	−2·7	—
28	29·819	+0·002	62·1	+3·6	—	28	29·756	−0·008	62·7	−1·1	—
29	29·579	−0·238	61·4	+2·9	1·236	29	29·715	−0·049	65·3	+1·5	0·096
30	29·692	−0·125	58·5	0·0	0·072	30	29·773	+0·009	65·3	+1·5	0·065
						31	29·827	+0·063	62·7	−1·1	—

Mean Monthly Heights of the Barometer and Thermometer for the months of June and July in the years 1868–72, inclusive.

June.	Barometer.	Thermometer.	July.	Barometer.	Thermometer.
	Inches.	°		Inches.	°
1868	29·949	61·8	1868	29·864	66·0
1869	29·871	56·5	1869	29·864	64·0
1870	29·891	61·1	1870	29·761	64·9
1871	29·708	55·2	1871	29·621	60·5
1872	29·668	58·0	1872	29·708	63·8
Mean -	29·817	58·5	Mean -	29·764	63·8

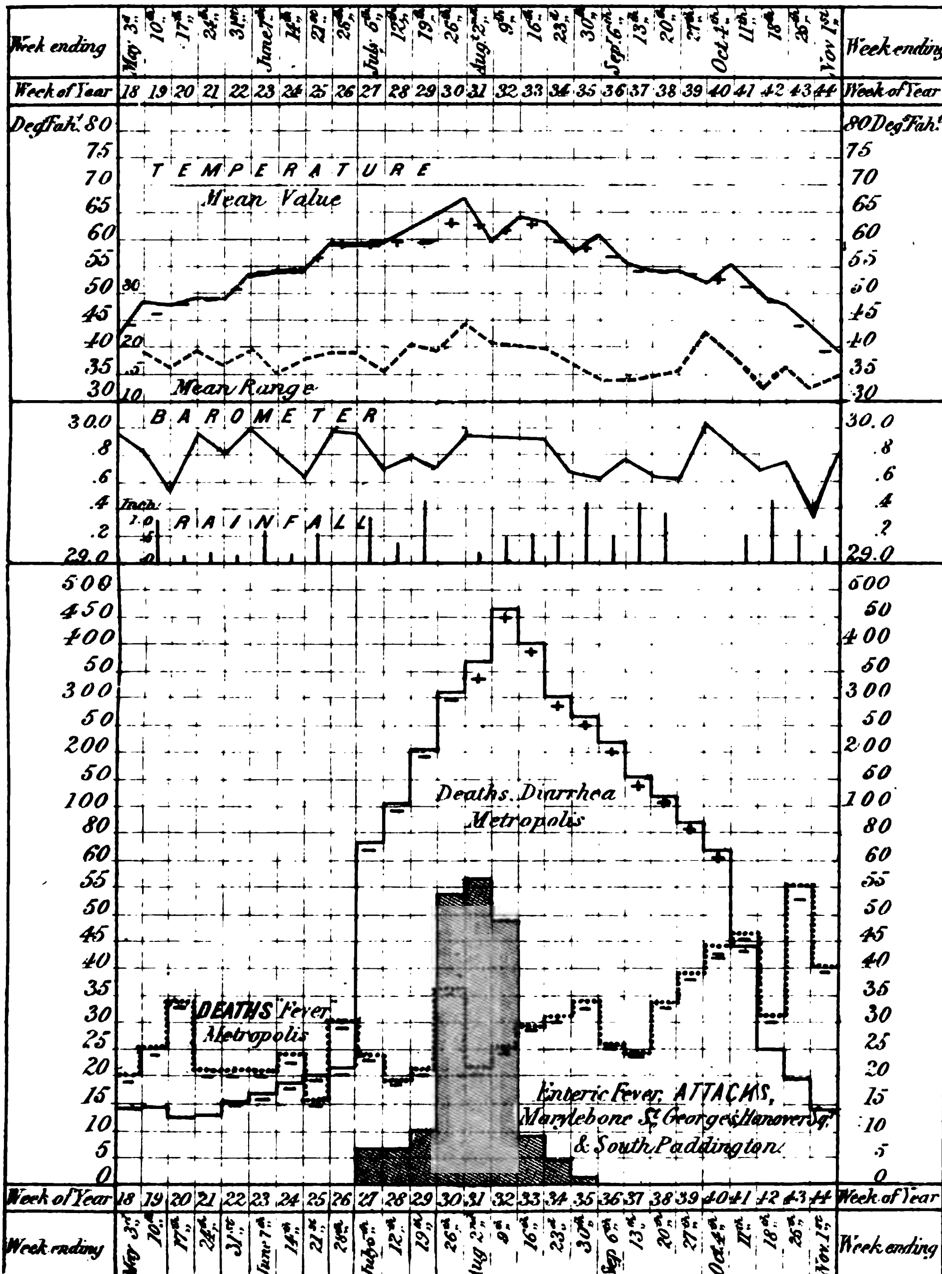
(Signed) Robert Main.

February 10, 1874.

(To illustrate Report on Prevalence of Enteric Fever in certain districts of West London.)

APPENDIX DIAGRAM No. I.

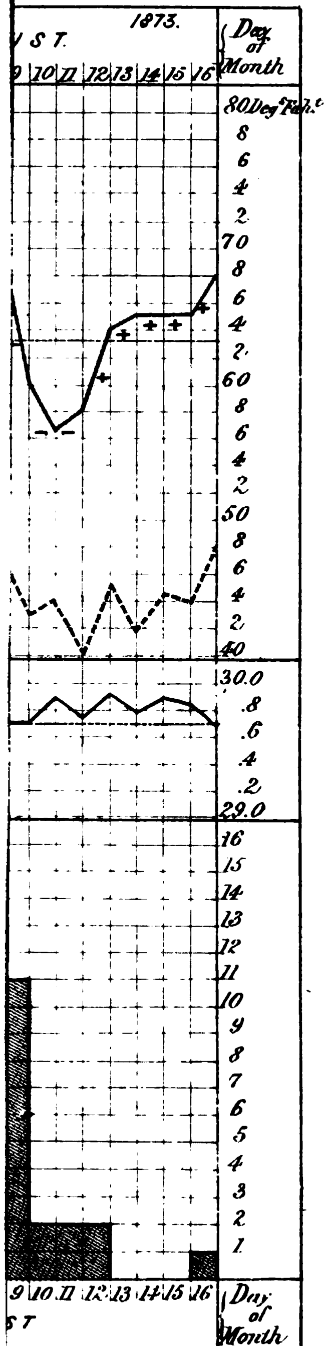
Showing the relations of the Outbreak to the Mortality from "Fever" and "Diarrhea" in the Metropolis generally to certain Meteorological Data.



Danfertield Lith

West London

Showin... to certain Meteorological Data.

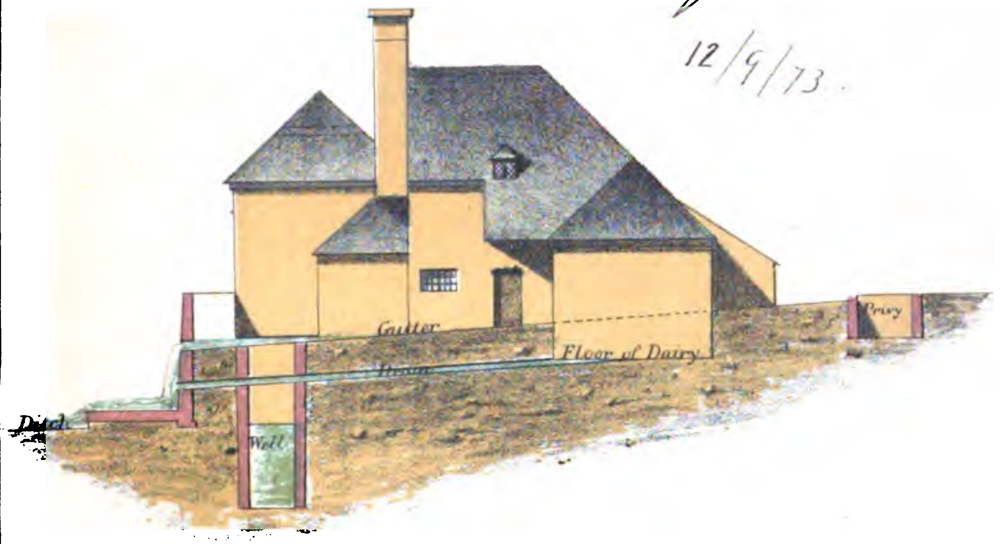


(To illustrate Report on Prevalence of Enteric Fever in West London).

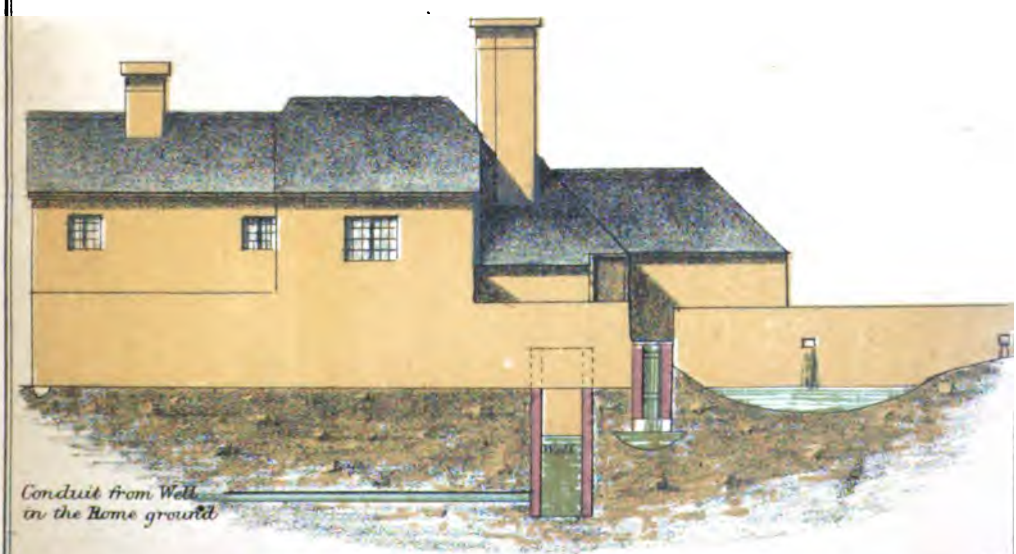
SECTIONS OF CHILTON GROVE FARM.

Henry Morris
Surveyor

12/9/73.



SECTION FROM NORTH TO SOUTH.



SECTION FROM WEST TO EAST.

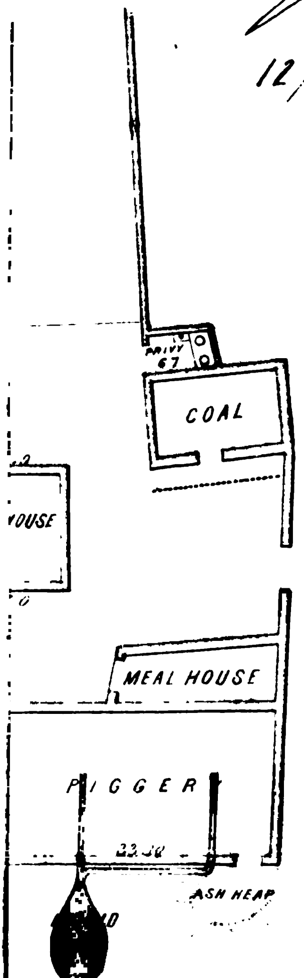
Scale 1 Inch 16 Feet.

Dangerfield, Lith. London

(To illustrate A

LAN OF GROVE FARM

nry Morris
Surveyor
12/9/73



The position of the Ash-heap and of the Drain for the liquid dung is drawn from a plan and notes made by Mr. Radcliffe. 13th Aug. 1873.

Dangerfield, Lith. 22. Bedford St. Covent Garden

No. 7.

REPORT by Mr. J. NETTEN RADCLIFFE on CERTAIN MEANS of preventing EXCREMENT NUISANCES in TOWNS and VILLAGES.

CONTENTS.

PRELIMINARY.

Privy Council Inquiry of 1869.

In 1869, Dr. Buchanan and I, as inspectors in the Medical Department of the Privy Council, made an inquiry concerning the systems then in use in various northern towns for dealing with excrement. The considerations which prompted that inquiry were thus stated in the introduction to the report in which we gave the results * :—

"The propagation of certain epidemic diseases, especially cholera, enteric fever, and diarrhœa, among communities, as the result of excremental pollution of air and water, is one of the best established facts of sanitary medicine. It is a fact which has been admitted for over a century, and still various inquiries of this department (themselves affording repeated evidence of its truth and importance) are showing that it remains without practical recognition by a large proportion of the health authorities of the kingdom. It must be allowed

* On the Systems in use in various Northern Towns for dealing with Excrement.—Twelfth Report of the Medical Officer of the Privy Council, 1869.

App. No. 7.

On Excrement Nuisances, by Mr. J. Netten Radcliffe.

that this inaction has been mainly due to the ignorance, or the parsimony, or the carelessness of the bodies to which sanitary matters have been entrusted, but the whole extent of the inaction cannot thus be explained. Certain authorities have, indeed, been glad to have, as a handy excuse for delaying to take any step whatever towards amendment, the want of agreement throughout the world as to the means of amendment. But there are other authorities which have fully recognized the importance of efficient and safe excrement removal, which have made themselves acquainted with the defects of their own arrangements, and which have seriously inquired as to means of improvement; and yet even these authorities have, after all, been as little satisfied with any proposed alternative as with their own acknowledgedly bad system. No one who knows what many of these latter bodies have done in other ways of sanitary improvement, especially in the matter of water supply, can imagine that inaction in their case is without some reasonable cause. For the health of their communities has justifiably not been the only care with such authorities. There are other considerations which they have held in view; and the chief of these, in a sanitary aspect, is that the disposal of the excrement shall be done without detriment to other people; while in an economical point of view the question has pressed how there shall be restored to the earth for the sustenance of vegetation the elements which have been taken from the earth by vegetation for the sustenance of animals. The attainment of such objects has affected materially the ability and the disposition of authorities to deal with the primary sanitary aspects of excrement disposal.

"The department, in its investigations as to the local prevalence of disease, has been constantly brought face to face with this state of matters. Its inspectors, when they found places wanting in proper arrangements for excrement-disposal, have of course insisted on the mischief arising from this source, and on the need for improvement. But, especially where the local authority has itself been conscious of defects in its arrangements, and has already entertained schemes of amendment, yet without practical result, advice in general terms has been felt to be somewhat vague and unpractical. Evidently it would be helpful to the action of the local authorities in such circumstances to know what plans are being carried out in various other towns of the kingdom, and to have materials before them for judging how far any of such plans might prove applicable to their own wants, at all events for immediate purposes, and until better agreement should be attained as to the constructive arrangements that constitute perfection in regard of excrement-disposal."

With this object in view we examined and reported upon the arrangements for excrement-disposal in various northern towns; and in addition to describing such of them in detail as we thought it might be useful for other places to know, we endeavoured to determine, from the results of the investigation, certain general principles of action in the abatement of excrement nuisances which might serve as a guide to local authorities.

Scope of present inquiry.

The present inquiry (1874), carried out under the Local Government Board, included also a further investigation of the dry-earth system, which had been dealt with and reported upon by Dr. Buchanan* independently in the first inquiry. The inquiry was directed to ascertain the additional experience which had been gained in the working of the various systems of excrement-disposal described in the previous reports, and generally such new experience as might have been obtained on the subject during the five years which had elapsed since the first inquiry; and for this latter purpose it was extended over a wider area. The subject of nuisance from "slops," which is in some sort complementary to that of excrement nuisance, was, moreover, included in the present inquiry.

* On the Dry-Earth System of dealing with Excrement.—Twelfth Report of Medical Officer of Privy Council, 1869.

In pursuit of this inquiry the following places were visited :—

1. Aldbury.
*2. Birmingham.
3. Birkenhead.
4. Bradford.
5. Bristol.
*6. Broadmoor.
7. Butleigh.
8. Cockermouth.
9. Dalmuir.
*10. Dorchester.
11. Eastwick.
*12. Edinburgh.
13. Exeter.
14. Gaddesden (Little).
*15. Glasgow and vicinity.
16. Gloucester.
*17. Hull.
*18. Halifax.
*19. Halton.
20. Hereford.
*21. Leeds and adjoining district.
22. Lands End district.
*23. Lancaster.
*24. Liverpool.
*25. Manchester.
*26. Nottingham.
27. Oldham.
28. Paisley.
*29. Rochdale.
*30. Salford.
31. Sinningrove (Yorkshire).
*32. Saltaire.
33. Shenfield, Essex.
34. Shildon (Bishop Auckland).
35. Sunderland.
36. Scarborough.
37. Slough.
38. Tring.
39. Upleatham.
40. Wakefield.
41. Wandsworth.
42. Warrington.
43. Westbury-on-Trym.
44. Whittingham.
45. Walsall.
48. Worksop.
*49. Wimbledon Camp.

In the following report I do not propose to give in detail the results of inspection in each place, but to describe only such of the several inspections as appear to me most instructive in their bearing upon the subject of the report.

A.—SUMMARY REPORT.

I.—GENERAL OBSERVATIONS.

Progressive advance in adoption of measures of excrement disposal.

Reviewing the general results of the inquiry it is desirable to state, first, that while it has disclosed a very assuring advance, during the past five years, in measures adopted in numerous places for the abatement of excrement nuisance and some important modifications of detail in the measures adopted, the conclusions of the previous inquiry remain substantially unaffected. I may be permitted also to remark, that in the course of this inquiry frequent and most gratifying testimony was given of the usefulness of the previous inquiry as helpful of the action of local authorities, for which purpose it had been originally designed.

Necessity for alternative measures.

This inquiry, as the previous inquiry, was restricted to measures of abating excrement nuisance other than water-sewerage, except in so far as it seemed advisable to include particular adaptations of this mode of excrement-disposal to the wants of those sections of a community which are most dependent upon public arrangements and public supervision. The inquiry, in fact, began at the point where it had been assumed,

* The 17 places marked with an asterisk in the above list had been visited in the first inquiry, as also had been two places, not now revisited, Preston and Stamford.

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On Excrement Nuisances, by Mr. J. Netten Radcliffe.

for whatever reasons, that the applicability of water-sewerage to the needs of a community, in respect to excrement-disposal ended; and it designedly included within its range only so much of the question of water-sewerage as was necessary to elucidate certain presumed difficulties of application to particular sections of the poorer classes. It was simple matter of observation that, previous to the first inquiry, water-sewerage which to that time had been the only system of abating excrement nuisance generally advocated in this country, had been regarded as inapplicable to the wants of numerous places where neither ignorance, nor parsimony, nor indifference to sanitary responsibilities could be justly assumed of the local authorities; and that, excepting only such measures as were described in the report of Dr. Buchanan and myself, in these and many other places, sanitary work to this particular end had come to a dead lock. The unquestionable and preponderating advantages of a system of water-sewerage in regard to decency, convenience, and wholesomeness, as compared with other systems of excrement disposal then commonly in use, had naturally so influenced the judgment of most persons concerned in promoting sanitary work, as to cause them to desire its general introduction. It was not until the institution of the system of medical inspections as to local prevalences of disease, established by the Privy Council, came into operation, that it began to be understood how partially water sewerage had been carried into operation in the kingdom since the enactment of the Public Health Act, 1848, and how grave a state of things had persisted in many places, and become aggravated in others, from lack of some alternative methods of abating excrement nuisance. I do not propose to discuss here the various circumstances under which this had come to pass. It is sufficient for my present purpose to state that they commonly depended either upon local peculiarities which precluded the adoption of water-sewerage, except, perhaps, under conditions of combination of authorities too remote to be contemplated as a practical matter; or upon local habits of thought and practice which gave little hope of speedy change, and which must be recognised as elements of judgment in making recommendations for the sanitary amelioration of a place if any hope were to be entertained of these having effect. It had become clearly obvious, in fact, at the time of the first inquiry, that the exclusive recommendation of one particular method of excrement-disposal could no longer have place, if the inspections referred to were to be productive of good, the dead lock in which sanitary authorities were very generally found loosened, and sanitary work throughout the kingdom quickened. This broader view of the question, moreover, appeared to be more consistent with the intentions of the Legislature as indicated in the various Sanitary Acts. For these Acts permit one or other or all of several different ways of depositing excrement, under the general condition that nuisance is to be avoided in the arrangements adopted.

While these considerations had arisen out of the medical inspections instituted by the Privy Council, and had in effect determined the inquiry which was carried out by Dr. Buchanan and myself under the instructions of their Lordships, the local authorities of several northern towns had given serious attention to the same subject as a matter of local administration. Although rejecting a general system of water-sewerage, they had regarded with increasing anxiety the persistence or growth of excrement nuisance within their districts, and, as shown in our report, had cast about to seek its abatement in several ways, other than water sewerage, having at the same time regard to the utilization of the excrement. The wisdom of this course of action, viewed from a medical stand point and gauged by a large dimi-

nution of excrement nuisance in the places where it had been most successfully carried out, was made abundantly clear in the first inquiry, and has been amply confirmed in the present inquiry. The necessity of such a course must, indeed, be accepted if any general progress is to be made in dealing with excrement nuisance throughout the kingdom. Upon this question the experience of the Medical Department, based upon the minute study of local prevalences of disease, is in complete accord with the not less important results of local experience in overcoming practical difficulties connected with excrement nuisance. It was inferred from the first kind of experience, and it is the obvious deduction from the latter kind of experience that the requirements of each place as to excrement-disposal should be judged not from any general preconception of what is the best mode of such disposal, but from a careful consideration of the various modes at command which would best meet those requirements and the habits of the people. Without seeking to suggest a limit to human invention and ingenuity, I may say that nothing in the course of this inquiry has given even an inkling of support to a rather prevalent notion that some perfect scheme of excrement-disposal, applicable to all sorts of places irrespectively, may be looked for, and action properly deferred until such scheme be forthcoming. The more closely the facts are looked into relating to the different conditions under which various populations live, the more surely I am persuaded will the conclusion be arrived at that no reasonable ground exists for anticipating the fulfilment of such hope within any period of time which would justify a local authority delaying action on account of it.

II.—Systems of Excrement-Disposal Observed.

(a.) *General Considerations.*

Systems of excrement-disposal observed, 1874.

In one only of the places visited in the course of the inquiry did a uniform system of excrement-disposal exist. Bristol has a general system of water-sewerage, and this was the only town having such a system, properly so-called, which came within the scope of the inquiry. In the other places waterclosets existed as a part of the system of excrement-disposal, in some places many in number, in some few.

Water-closets existed in conjunction with a plan for the daily removal of excremental matters from localities where closets could not be fixed, and with a plan of public dry-ash closets in Edinburgh; with midden-closets in Birkenhead, Bradford, Eastwick, Hull, Liverpool, Worksop, &c.; with midden and pail closets in Birmingham, Halifax, Leeds, Manchester, Nottingham, Rochdale, Salford, Sunderland, Scarborough, Wakefield, &c.; with midden-closets and earth-closets in Lancaster, &c., and with midden, pail, and charcoal-closets in Glasgow. In a few rural districts only did waterclosets wholly disappear; and certain hamlets and villages were observed in which the midden-closet (Upleatham mines) or the midden-closet and earth-closet (Sinningrove, Shildon, &c.), or the midden-closet and pail-closet (villages near Cockermouth) alone existed.

Principles of excrement-disposal.

This conjunction of different plans in various towns represents mainly, in the present state of things, a transitional condition from the common middenstead privy with its great accumulations of filth and abominable offensiveness, to a better system. In almost every place the watercloset has become, from the sentiment of cleanliness attending its use and the privacy which attaches to it as commonly adapted to buildings, the favourite method of the educated and wealthy; and amid much discussion of the subject, I have seen no indications of this prepossession in its favour undergoing any great change. It will be more difficult for those classes to unlearn the use of the watercloset and

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adopt any of the plans yet offered in substitution for it, than to unlearn the use of the midden-closet for which it was substituted. In some of the places visited, in Edinburgh and Glasgow, for example, the tendency is to make a watercloset system general, and existing supplementary scavenging of excrement, by pail-closets or improved midden-closets, must be regarded as provisional pending the solution of difficulties in the structural arrangements of houses and in the disposal of sewage; although as yet no limit can be indicated when these provisional arrangements may end. In Hull an improved midden system is the complement of water-sewerage; and in Rochdale and Manchester a pail-system is rapidly becoming so. This combination of two or more methods of excrement-disposal in the same place is commonly the result of deliberate efforts to abate a grave nuisance consistently with the believed special wants of a population. In those places where plans complementary to a watercloset system have been most successfully introduced (*e.g.*, Edinburgh, Hull, Rochdale, Manchester, Nottingham), success has been obtained from certain well-defined principles of action which appear to me to be essential to successful work of the same kind elsewhere.

Frequency of removal.

Foremost amongst these, and regulating all that follows, is *the frequency of removal of deposited excrement.* The arrangements to this end must of necessity govern all other arrangements, and it is requisite that they should be first determined by a local authority. The peculiar advantage of the watercloset is that with properly arranged and rightly constructed drains and sewers, and duly supplied with water, it admits of excremental matter being removed without offensiveness beyond the precincts of a house and from amidst a community immediately after it has been deposited.* Dr. Buchanan and I, in discussing the period during which excrement should be permitted to remain in the vicinity of dwellings, expressed ourselves, in 1869, in the following words, which I reiterate now:—

"In the present imperfect state of our knowledge of the conditions under which fæcal diseases spread, we do not feel ourselves entitled to say at what time, after being passed, dejections are or may (under various external circumstances) become dangerous to health. We cannot say this either in regard of healthy excrement, or of that passed from persons affected with disease, specific or other; but we think it may probably be taken as sufficiently true for practical purposes that there is little chance of mischief from the storage of excrement *for a day,* even though along with healthy excrement that of persons affected, for example, by enteric fever should, without proper disinfection, chance occasionally to be included. We propose, then, to regard *complete removal of all excrement within a day* as practically constituting safety in the case where excrement is unmixed, or is only mixed with ashes."

In Edinburgh only has such a frequent removal as is here suggested been successfully carried out by scavenging arrangements, and it appears to have been very generally thought, I hold most mistakenly, that the peculiar circumstances which originally led there to the adoption of this

* The fundamental principles of house drainage and sewerage are set forth in the "*Suggestions as to the preparation of Plans as to Main Sewerage and Drainage* "*and as to Water Supply,*" prepared by Mr. Robert Rawlinson, C.B., C.E., Chief Inspector of the Engineer's Department, and published under the authority of the Board. Particular applications of these principles, essential to the inoffensive removal of excremental matters by the watercloset, consist (*a*) of the introduction in the course of the drain, after it has passed outside the walls of the building, of a contrivance, forming ordinarily a trap, open to the air, for the purpose of cutting off direct communication between the sewer or other termination of the drain and the portion of the drain and its connections within the house; and (*b*) of abundant provision for the ventilation of soil-pipe, drain, and sewer.

arrangement remove it from consideration elsewhere. Leeds is now engaged experimentally in a plan of daily scavenging of its worst district. In this town the conditions are very similar to those which are found in many English towns. The mode of scavenging adopted here may probably provoke objection, but the enormous advantage to the district by the systematic daily removal of all excremental filth cannot be gainsaid, and it will be a deplorable result if from any matter of remediable detail, or for financial reasons, this important experiment should prove abortive. In not a few towns (as for instance Cardiff) all dry house refuse is removed daily, and I am unable to believe that what has been found practicable with this comparatively harmless stuff should not be practicable of excremental matters.

The frequency of the scavenging governs the size of the receptacles for excrement. Hence the primary consideration for a local authority in respect to the abatement of excrement nuisance is the arrangement of the "night-soil scavenging," so-called. In Hull, and Rochdale, and Manchester, and Nottingham, and the towns which are systematically using a pail system, scavenging at weekly intervals has been adopted as the most practicable general arrangement, and the middensteads of Hull and the pails of the pail-closet towns have a capacity regulated by this frequency of removal. That is to say, they are designed to hold a week's excrement of a household and no more.

Capacity of receptacle.

The want of clear recognition of the principle that systematic frequent scavenging is the initial consideration in improved methods of excrement-disposal other than water-sewerage has led to much fruitless work in attempts to improve the midden system. *The measure of the capacity of the receptacle should be the frequency of scavenging.* With even a weekly scavenging it is obvious that the receptacle, if no larger than is required to contain the excrement in the intervals of removal, will almost of necessity be free from the evils which attach to the structure of the old middenstead privy. There is no necessity for a privy pit, as commonly understood, and all the evils of soakage of excrement into the soil and saturation of walls in addition to accumulation are at once done away with, while the structural requirements to prevent offensiveness are rendered of the greatest simplicity; and better still, it becomes at once possible to substitute a handy moveable receptacle with all its advantages for a fixed one.

(*b.*) *Particular Modes of Excrement-disposal observed and the Results of Observation thereon.*

The several modes of excrement-disposal observed in the course of the inquiry may be classified as follows:

1. *The Midden System.*
2. *The Pail System.*
3. *The Water System.*
4. *The Earth System.*
5. *The Charcoal System.*

On each of these systems, with the exception of the charcoal system, and with certain limitations as to the watercloset system, Dr. Buchanan and I reported in 1869, and we then endeavoured to set forth the principles which should govern their use. These principles remain wholly unaffected by the results of the present inquiry, and only such change is necessary in the phraseology that we then used in stating them, as is requisite to include sundry modifications of detail.

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The Midden System.

The different arrangements observed in operation on this system were as follows:

1. Midden-Closets with fixed Receptacles:—
   - a. *Of old type,* old parts of almost all towns.
   - b. *With middensteads of large size, and permitting much accumulation, but compulsorily supplied with some means for keeping the contents dry (covers, drains, or both), and for preventing soakage into the earth.* Leeds, Birmingham, Nottingham, Bradford.
   - c. *The same* (though generally with smaller middensteads) *with the addition of special construction aiming at the effectual covering of excrement by ashes—*
     - *By sloping bottom* (Nottingham, Salford).
     - *By hinged seats or steps* (Manchester, Salford, Saltaire).
     - *By grid and shoot* (Bradford).
     - *By shoot* (Glasgow).
   - d. *The same arrangement, but with the middenstead reduced to a mere space under the seat* (Hull).

2. Midden-Closets with moveable Receptacles.
   - *A tub used as middenstead and placed beneath the privy seat (Nottingham).*

1. *Midden-Closets with fixed Receptacles.*

Midden-closets with fixed receptacles.

Starting from the old-fashioned pattern of midden-closet as the standard of all that is utterly wrong, the experience of both inquiries shows that midden-closets may be improved, and that if the following conditions be observed they may be regarded as tolerable:—

Position.

1. As to *position.*—It should not be permissible for a midden-closet to be placed under rooms or workshops, or with its walls in juxtaposition with those of a house. Whatever stone, brick, or cement be used in building the middenstead (privy-pit) it must be assumed (regard being given to the conditions under which the work of construction is commonly executed) that some amount of oozing will occasionally, if not habitually, take place. Again, a midden should not be permitted in any place from which its contents cannot be removed without taking them through houses. Dr. Trench's code of regulations under which middens are tolerated in Liverpool expresses these principles in detail.*

Materials.

2. As to *materials.*—The materials of which the middenstead is con-

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* This code (see p. 205), provides against—
"1. Midden privies inside houses.
"2. Midden privies emptied through houses.
"3. Midden privies situated beneath rooms.
"4. Tunnel middens of every description.
"5. Combined open middens supplying many tenements and placed near to inhabited rooms.
"6. Midden privies of private houses clustered together in a blind court.
"7. Midden privies of private houses in close confined yards or situated beneath windows, or abutting on walls of houses, or within two feet of the lower windows, or of the door of the house.
"8. Midden privies of courts.
"9. Midden privies abutting on, or opening directly into, streets and thoroughfares, and emptied before the doors and windows of houses.
"10. Midden privies of front houses when emptied through a court.
"11. Midden privies beneath the footpath of the street, and emptied through a grid on the footpath.
"12. Midden privies of many houses, when collected together as a kind of amphitheatre, as is seen in particular groups of streets."

structed should be to the greatest possible extent non-porous, that liquid may be prevented soaking into as well as through them.

Roofing.

3. As to *roofing*.—It is of material importance that a middenstead should be roofed over, for all water helps decomposition, besides increasing the difficulty of removing the contents.

Ventilation.

4. As to *ventilation*.—When the middenstead is roofed ventilation should be insisted upon. Whether this should be effected by shaft or otherwise will depend upon the position of the privy to the house or to neighbouring houses. In Manchester special ventilation of the middenstead by shaft is ordered on account of the habitual contiguity of the privy to the house, and in the conversion of midden-closets into pail-closets now going on in that city, it is still held advisable to retain the ventilating shaft for the place containing the pails. The closet, as distinguished from the middenstead, should also be freely ventilated. It has been particularly observed during the recent inquiry that differences of offensiveness in midden-closets were greatly dependent upon the free access of air both to the middenstead and the closet.

Drainage.

5. As to *drainage*.—Drainage of the middenstead is fatal to any possible defence of a midden system at all. If urine with the liquid and partially dissolved fœces be conveyed out of the middenstead into sewers, there can be no sufficient reason either commercial or sanitary for not sending all excrement together along sewers. Drainage is fallacious as the means of continuously draining off the liquid contents of a middenstead, and thus promoting dryness of contents, as was observed everywhere in wetness of open middensteads presumed to be drained; and dryness can be secured in other and more effectual ways. Drainage proves, moreover, a source of hidden mischief by permitting liquid and partially dissolved excrement to trickle into the drain, carrying along with it fine ashes, the mingled excrement and ashes not unfrequently almost wholly blocking up the drain. In illustration of this state of things, the result of explorations made in Manchester into the state of drains communicating with middensteads, and given in the report on that city, may be referred to.

Size and shape.

6. As to *size* and *shape*.—It is most desirable that the area from which foulness might sink into the soil should be as far as possible within sight, not sunk beneath the surface; and then it should be as small as can be contrived. In this view, as adapted to a single family, the new Hull middenstead may be indicated as the most satisfactory which has come under observation; as adapted to several families, the new Glasgow middenstead.

The *Hull middenstead,* which is designed to serve for a week for one family, consists solely of the space under the closet seat, and its floor commencing above the ground level (on the level of the closet floor) is formed by a flag which slopes downwards to the back wall at the ground level there.

The *Glasgow middenstead* is proportionately of smaller size than the Hull middenstead, and is formed by the space beneath the closet seat and about equal space in rear. The floor is slightly sunk beneath the level of the ground, and in this respect the construction is objectionable, and should be changed to the Hull pattern. This middenstead is arranged to contain two days' accumulation of excrement and house-refuse of the families using it.

Since largeness of size means infrequency of emptying, the middensteads can scarcely be too small, and by far the most satisfactory constructions which have come under observation, for the particular requirements they were designed to meet, are the new Hull and Glasgow middensteads.

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In some instances the *middenstead bottom* has been rounded, as in plans approved at Nottingham and elsewhere, with the object of the ashes becoming better mixed with the excrement in the middenstead. Experience of this arrangement proves that the end sought is not obtained by it. Regard being had to the nature of ordinary building materials, as meeting the condition of imperviousness, a flat surface of stone or slate appears to answer best.

Disposition of contents.

7. *Disposition of contents.*—The *covering up* of the excrement with ashes and dry house refuse, or by ashes alone, should be considered as essential in any scheme for the retention of middensteads. Numerous plans of so-called improved middensteads have come under observation principally designed to secure this end, but the arrangements of the Hull and the Glasgow middensteads have alone in practice appeared to ensure any reasonable degree of success. In the Hull middenstead the ashes and other dry house refuse are simply cast through the closet seat upon the excrement; in the Glasgow middenstead they are thrown into it behind the closet seat, but are directed upon the excrement by an inclined plane. In both instances the small capacity of the receptacle is an element of success. Other schemes, intended to diminish the offensiveness of *large* middensteads, as observed in Manchester, Salford, Nottingham, and elsewhere, have uniformly failed.

The indiscriminate casting of ashes and house refuse upon the excrement diminishes the value of the latter as manure, and many plans exist for covering the excrement with fine ash only, the cinders being separated for reburning. The greater number of these plans are designed somewhat after the fashion of the Bradford plan, and in practice, so far as they have come under observation, have proved quite futile. In the Bradford plan the sifting of the ashes is effected by a riddle so placed in rear of the closet, that the fine ash as a rule fall clear of the excrement. In the dry-ash closets of Manchester and of Morrell's patent it has been shown that it is quite possible to devise and ensure the use of sifters so as to secure the covering up of the excrement. It may be possible to adapt the same means to the common middenstead, but no examples of such adaptation have come under observation.

Access.

8. As to *access.*—Removal of the contents of the midden through the house has already been condemned. The scavengers' access to the privy, where the cleansing is done by the public servants, should invariably be direct from without; and if the middenstead be not simply the space beneath the seat, the opening for removal of the contents should be under his sole control.

Closets.

9. As to *construction of closet.*—The lower parts of the wall and floor should be of impervious material, and the floor should slope somewhat towards the door. In this way a broom and pail of water will well clean out any casual impurity. The closet, as already stated, should be ventilated as thoroughly as practicable.

Holding in view the conditions seen in actual practice, and combining them so as to give what appears to be the least objectionable forms of midden-closet with fixed receptacles, the following results are obtained :—

(*a.*) A closet, removed from the house, roofed and floored with sloping flags, the upright of the seat and the seat itself moveable; the space under the seat, constituting the middenstead, made of non-porous material, with its floor at the level of the ground, sloping backwards, and undrained. If the quantity of ashes applied to the excrement with this construction do not suffice to keep the contents solid, there cannot be any presumption in

favour of a midden-closet at all. The roof of the closet serves to keep rain out of the middenstead, and as much ventilation as procurable is given. The type of this simple, inexpensive, and least harmful midden-closet is found at Hull. The upright of the closet-seat, however, in the Hull plan, has the defect of being porous.

(b.) The same construction as to roof, floor, and absence of drainage, but with the closet seat fixed, and the space beneath it extended sufficiently back to admit of the ashes and house refuse being thrown upon the excrement, directed by an inclined plane, from the rear. The type of this equally simple privy is found at Glasgow.

Having arrived at these particular modifications of the midden-closet, as being those from which the worst defects of the system are found absent, it must be observed, that *the one great condition under which such closets are alone permissible, is the frequent removal of their contents.* It is unnecessary to dwell upon a sanitary truth so certain as that excrement, if it is to be stored at all in the vicinity of houses, along with no better guard than ashes, should be stored for the shortest possible space of time. In Glasgow the contents are presumably removed every two days; in Hull once a week; and the capacity of the middensteads is calculated in each case to contain only the filth and refuse which accumulates in the intervals of the scavengers' visits. The plan of weekly scavenging of night-soil is at present held alone feasible as a general practice in those towns which have adopted systematic measures for abating midden nuisance; but special arrangements are commonly made for scavenging at more frequent intervals particular houses, such as lodging houses, or districts where greater frequency is obviously called for. The important principle in fact is steadily becoming recognized, that where it has not been found practicable as yet to bring the intervals of scavenging for a whole place within those limits which considerations of health render desirable, a different rule should be applied to the least wholesome localities of the place, by scavenging these more frequently—thus regulating the scavenging by the greater or less degrees of filthiness or liability to filthiness of particular localities.

2. *Midden-Closets with moveable Receptacles.*

Midden-Closets with moveable receptacles.

The Nottingham pail-closet is, in reality, a closet with moveable middenstead. It constitutes the link between the pail-closet system and the midden system, and while finding a place in both systems is most usefully considered here. The Nottingham pail-closet, in fact, combines the advantages of the pail-closet with the simplicity of the midden-closet. The substitution of the pail for the middenstead at once removes the various structural difficulties which beset the building of a middenstead so as to remove its unwholesomeness, and permits that effectual removal of the contents and cleansing of the receptacle which attach to the pail system.

The closet is of the same simple construction as the Hull midden-closet, but the floor on which the receptacle stands is flat. The seat is hinged and the front moveable. The pail used beneath the seat is formed, as the pail used at Rochdale, of half a disused paraffin cask, and has an outside diameter of about 1 ft. 7½ in., and height of 1 ft. 3½ in. One pail only is used, all the ashes and dry refuse going into it. The used pail, covered by a metal lid, is removed weekly or at shorter intervals according to the necessity of the case, and a clean pail is substituted for it. An ordinary open waggon serves for the purpose of

removal and change, a tarpaulin being thrown over the pails. The used pail is carried to the depôt, emptied, washed, and then charged with a small quantity of a deodorant and antiseptic (freshly prepared carbolate of lime) for re-use.

The plan followed in certain parts of Edinburgh, in which the excrement, ashes, and dry house refuse are deposited in moveable receptacles of various forms in the houses, and then carried daily to the street for removal by the scavengers, might be considered a variety of the midden system and included in the category under consideration. But this plan, as the result of a peculiar local necessity, is unconnected with any structural arrangement for privacy, and although it may be regarded as belonging to this system, it is, perhaps, more accurately classed apart.

Pail System.

Pail system.

The pail system was observed in the following forms :—

(*a*.) *Pails used without preparation* (Glasgow).
(*b*.) *Pails supplied with a deodorant and antiseptic* (Rochdale, Birmingham, Nottingham, Leeds).
(*c*.) *Pails lined on the Goux system* (Halifax).
(*d*.) *Pails in which ashes and house refuse as well as excrement are deposited* (Edinburgh, Nottingham).
(*e*.) *Pails into which fine coal ashes are screened above the excrement* (Manchester, Salford, Cockermouth).

Pail.

1. As to the *pail*.—Two pails are used for each closet in the pail system as fullest developed, one for the reception of the excrement, the other for ashes and house refuse.

For excrement.

The *excrement pail* in ordinary use is either a wooden pail, such as that adopted in Rochdale, Nottingham, and Halifax, or a metal pail, such as that used in Manchester, Leeds, and Glasgow. In the more recent adoptions of the pail system the metal pail appears to be most approved, but the long experience of Rochdale is in favour of the wooden pail for domestic use. A metal pail is used in that town for factories only, and it is said to be more apt to get out of order, and to have a tendency to corrode at the bottom. Wooden bottoms, are, in fact, being substituted for the metal bottoms here, when these pails need repairing.

Angular wooden boxes, which were at one time used in Leeds, are found objectionable, from the difficulty of cleansing them. The Rochdale excrement pail has a capacity of 10 gallons ;* and it is undesirable, on account of handiness as well as on account of capacity, that pails of larger size should be used.

For ashes.

The *ash-pail* in Rochdale is a wooden pail of somewhat larger capacity than the excrement pail. In Manchester it is a rectangular box of handy dimensions. Elsewhere other forms of pail or tub are used. In Glasgow, an ash-pit is attached to the closet. A fixed ash-pit necessarily leads to much of the evil peculiar to the middenstead, for the contents of chamber utensils are liable to be thrown into it. This evil is not found to arise to any considerable extent with moveable ash receptacles. The nature of the receptacle acts as a check upon the practice, and the frequent removal of the contents enables a supervision to be maintained over it which operates very beneficially in preventing wilful carelessness or misuse.

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* The Rochdale pail, if filled, will hold 100 lbs. of excrement and urine as usually passed at stool ; the average weight of the contents of a pail, after one week's ordinary use by a household, is 41 lbs.

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2. As to the *closet*.—The arrangement and structure of the closet is very much the same as that which has been described as the best form of midden-closet, the floor being in this case made level for the reception of the pails, both pails in the most satisfactory form of closet being included under the same roof. It would be difficult to suggest any great improvement upon the patterns adopted in Rochdale, Manchester, and Halifax. The compactness of the plan, and the facility with which the pail-closet can be adapted to the varied requirements of old towns in the reconstruction of midden-closets is most instructively shown in the plans given of adaptations in Halifax.

Closet

3. As to *preparation of the excrement-pail*.—Thorough cleansing of the pail before use, and after each removal of contents, is necessary to the satisfactory working of the system; and dosing the cleansed pail before being placed in the closet with a deodorant and antiseptic (crude chloralum, as at Rochdale, or carbolate of lime, as at Nottingham) appears to act beneficially in retarding decomposition of the excrement and abating smell. The practice in Glasgow of simply tilting the contents of the pail into the scavengers' carts and returning the pail to the closet without scraping or brushing out the interior is bad, and the uncleansed pails are foul themselves, and augment foulness of the new contents by accelerating change in the excrement. Much importance is not to be attached to the lining of the pail, as regards absorbency, in the application of the Goux system to a mixed population; but the contents of the pails thus lined, as observed in Halifax, were less offensive to the eye than the contents of non-lined pails, and as little odorous, while the lining appeared to interpose some obstacle to splashing of the contents when the pail was used, and it afforded a ready and excellent cover to them when broken down either before or during removal.

Preparation of excrement pail.

The form of *lid* for covering the excrement pail during removal is not unimportant, and in this regard the Rochdale form as the result of longer observation and experience may be referred to.

Lid.

The *ash-pail* is simply emptied into the dust-cart, and needs no special preparation. But it is desirable that in those occasional cases where moist matters or slops have found their way into it, that the pails should have the "fur" which then collects on the interior surface scraped off. The dustmen should be provided with scrapers for the purpose, and be instructed to use them.

Ash-pail.

4. As to *working of the pail system*.—The *moveableness* of the pails is their great recommendation. If they were as a rule simply emptied into carts and replaced, the process would be quicker and infinitely less offensive than that of cleansing a middenstead of the old construction. But incomparably better than thus emptying them is the Rochdale, Manchester, Birmingham, and Nottingham plan of removing the tub with its contents, and substituting a fresh one. Nothing indeed can be better in this respect than the arrangements at Rochdale, which have formed the chief pattern upon which other towns adopting the system have acted. The full pail is covered by a tight-fitting lid, and the whole is carried off to the manure depôt in a properly constructed closed van; a fresh, clean pail, charged with a deodorant, and brought by the van, being placed under the closet seat, in lieu of the pail removed. Thus, without any offence, the excrement is gone. At the same time the contents of the ash-tub are tilted into a special cart, so that all the solid household refuse is removed together. Without approving the removal of excrement through houses, it may be observed, that on this plan it would appear possible that such transit can be made without notable offence.

Working of pail system.

The facility which the pail-system gives for *frequent thorough removal* is enormous. At Rochdale weekly emptying is the rule, but

many tubs are emptied two or three times a week. Other towns adopting a similar system have followed the same rule. Hitherto this removal has been effected during the ordinary working hours of the day, and the abomination of night scavenging to this extent got rid of. Obviously such frequent scavenging of middensteads could not be carried on at these hours without giving rise to incessant offence. Excrement collected by itself, or in combination only with ashes, ought not to be left in the vicinity of houses for a single unnecessary hour, and the plan of moveable pails permits of removal being effected more frequently than any other system in use in this country except waterclosets. Moreover, antiseptic agents can be very effectually applied under the pail system if special circumstances should cause them to be needed.

In this connexion it is impossible not to be struck with the advantage that a pail-system has in relation to diseased excrement. The facility and thoroughness with which any required chemical disinfection can be done, and the way in which the excrement itself can be wholly got rid of, leaving none of its products behind—nothing soaking into the ground or hanging about midden pits or sewers—obviously suggest most important powers possessed by this system for preventing the spread of excremental diseases.

5. As to *special adaptations of system.*—In Manchester and Salford a dry-ash system of excrement-disposal has been combined with a pail-system. Attached to the closet are arrangements by which ashes can be readily sifted, the fine ash falling by means of a shoot into the excrement tubs and covering the excrement, the cinders dropping into a receptacle whence they can be taken for reburning. The fine ash covering the excrement acts as a deodorant, and facilitates its subsequent manufacture into manure.

6. As to *general results.*—The pail system not only effectually does away with midden-nuisance, but, as carried out in Rochdale and Manchester, it is the only one which, while utilizing profitably all solid domestic refuse, appears to give promise of paying ultimately for the expense of its working.

The Watercloset System.

Watercloset system.

It is assumed here that the fundamental principles of the watercloset system are known, and so much of this system only has been included in this inquiry as would elucidate difficulties experienced in its application to certain classes of population. These difficulties are of two classes. The first class includes such as were described by Dr. Buchanan and myself in our report of 1869, as existing in London and other large towns, and which represent the difficulties attaching to the system when seen in its complete arrangements with water provided for every closet. The second class include the difficulties experienced in those towns and villages where waterclosets have been adopted, the supply of water to which has to be furnished by hand.

The first class of difficulties were thus summarised in the report of 1869:

> "A shoot or fragile pan, professing to be trapped, but with the trap almost certainly choked up, or knocked to pieces by the implement that has been used to get rid of obstruction; supplied, if in good order, with water by trickling from a small tap, but the tap usually either fixed or leaking wastefully all day long; no water in time of frost; almost universally filthy and stinking; and washed out (in a fashion to render the place unusable for hours) only every few days when the sanitary inspector is discovered to be in the neighbourhood."

The second class of difficulties, disclosed during inquiries into local

prevalences of enteric fever, consist of the insufficient flushing of the closet, and the blocking of the drains with excremental matter.

Two forms of watercloset have been devised to overcome the first class of difficulties, the *Liverpool Trough Closet*, and the *Tumbler Closet*; and a particular form of "eject," called the "*Bristol Eject*," is in use to obviate the latter class.

Liverpool trough closet.

The Liverpool *trough closet* was described in the report for 1869, as admirable in arrangement and working. The five years' additional experience of its operation confirms in every respect the opinion then formed of its perfect adaptability to the wants of a poor population. The closets are cleansed daily by the people using them according to a systematic rota; there is no waste of water, no injury from frost, and the whole of their machinery is worked regularly by the public scavenger. In addition to these advantages the wear and tear, owing to efficient original construction, has been remarkably small.

Tumbler closet.

The automatic action of the *tumbler closet* was designed to secure the regular flushing of the closet at arranged intervals independently of the persons using it. The conception is excellent, the application in practice has been most unfortunate. Local authorities and private individuals have alike contributed to frustrate the success of the closet, the former by arrangements preposterously ill-adapted, the latter by permitting the regulation of the water supply to be governed by considerations of economy, not always consistent with the sanitary object for which the closet was constructed. The tumbler closet appears to be capable of doing good work if due supervision of its action by the local authority and a proper supply of water can be obtained. An admirable report of the working of this form of closet in Birkenhead, by Mr. Francis Vacher, the medical officer of health, with the lessons to be deduced therefrom, is given elsewhere in this report.

Bristol eject.

The *Bristol eject* is a capacious and strongly constructed dip trap interposed between the privy "trunk," as the receptacle is termed, and the drain. This trap admits of the ready extraction from it of foreign matters cast into the privy, and from the strength of its construction it is not easily broken by efforts made to free it from obstruction. In this respect it has an important advantage over the waterclosets in ordinary use, but its successful operation among the poorer classes of Bristol depends, not upon this structural adaptation or on an abundant handy water supply, but upon the fact that the Corporation, through its servants, undertakes the responsibility of removing obstructions and seeing to its proper flushing among such sections of the population as are known from experience to be untrustworthy in these matters.

The Earth System.

Earth system.

The previous systems refer solely to the storage and removal, or to the removal alone, of excrement, and such dosing with chemicals or covering up with ashes and dry refuse as the excrement may have been submitted to, has been designed merely to diminish offence from it pending removal. The dry-earth system of excrement-disposal differs materially from the foregoing systems in this, that the earth, if used in sufficient quantity, while acting as an efficient deodorant, at the same time destroys the excrement as such, producing a uniform, inodorous, inoffensive, earthy mass. In this state, judging from the sight and the smell, it might seem as if the removal of the mixed earth and excrement from the vicinity of dwellings could with safety be greatly prolonged and the cost of such removal proportionately economised. In our present state

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of knowledge of this compost and of the precise mode of origin of diseases connected with excrement, such a conclusion would be premature, and for the present at least, the same principles should apply to the removal of the mixed earth and excrement from the vicinity of houses as apply to mixed ashes and excrement or to excrement alone. On the other hand, in respect to storage, the dry-earth system yields advantages of the greatest importance in dealing with excrement in isolated dwellings and scattered communities in rural districts where accumulation is not to be avoided.

As a means of abating excrement nuisance, the dry-earth system is of the utmost value. Not every kind of earth is applicable to the system. Clayey and loamy soils and surface mould are best; chalk is of little use; gravel and sand are worthless. Conditions of its proper application are that the earth, thoroughly dried and not too powdery, shall be applied in detail to each stool in quantities of not less than 1½ lb. This application may be made simply by a scoop, or by any of the various forms of mechanism which have approximated the earth-closet for convenience and cleanliness of use to the watercloset. Preferably the receptacle for the mixed earth and excrement should be moveable. Fixed receptacles should be constructed in accordance with the general principles laid down in regard to middensteads.

Important evidence of the facility with which the dry-earth system may be carried out in practice, and of its efficiency in the abatement of excrement nuisance, is afforded by the numerous instances in which persons accustomed to waterclosets have voluntarily substituted for them this system.

The Charcoal System.

The successful introduction of charcoal as a common means of abating excrement nuisance would be a gain of which it is not possible as yet to estimate the proper value. Hitherto the use of this great deodorant for the ordinary needs of a community as to excrement disposal has been precluded by its costliness. By the fabrication of charcoal from seaweed, and (as is stated) from street-sweepings, it would appear probable that charcoal may presently be put in the market at a price admitting of its being largely applied by sanitary authorities and others to sanitary uses. By the further proposition of Mr. Stanford to convert the excrement itself into charcoal, and to utilize it (in addition to other profitable utilizations) in abating nuisance from itself, a further important gain would be obtained in overcoming the difficulties of excrement-disposal, if it should prove successful in practice.

Charcoal, as used for the abatement of excrement-nuisance, requires to be applied in detail after the manner of dry earth, and with similar mechanisms, but a much less quantity of the material is needed for the purpose (one fourth, so stated). It is claimed for the mixed charcoal and excrement that it need not be removed from the receptacle more than once in twelve months; but the same observations apply here as have been made in respect to mixed earth and excrement. The claim is made upon a presumption which has no present substantial foundation; and the use of the system among a community should be governed by the same principles as govern other systems of removing excrement by cartage.

III.—Liquid House-Refuse.—Slops.

Slops.

The question of abatement of nuisance from liquid house refuse, in those cases where, as in isolated houses and small hamlets, it is not

found practicable to deal with it under the conditions applicable to sewerage in general, has been considered in the course of this inquiry. Several instructive and largely applicable modes of abating nuisance under these circumstances, all by securing the efficient utilization or inoffensive disposition of the refuse on land, have come under observation, and are detailed in the report.

IV.—Excrement-Disposal in Rural Districts.

Excrement Disposal in Rural Districts.

It is desirable that the application of some of the foregoing observations to certain of the requirements of rural districts should be more particularly indicated. Where a community of arrangements is practicable to the local authority there the same principles apply in the general provision of means for excrement-disposal, whatever the size of the place, whether hamlet, or village, or town. But there are numerous scattered communities, and scattered groups of dwellings, and isolated houses and cottages which cannot be brought within any common local scheme of arrangements for excrement-disposal. Also, there are numerous communities which, although living together in a space sufficiently compact for a general scheme, have belonging to them many houses with gardens or other cultivated land for which it is desired, and indeed, requisite to retain the whole of the excremental refuse of the household for manure, and for which the regulations of the local authority should make provision. In all such cases no hard and fast scheme of excrement disposal is practicable or advisable, and general success is probably only to be obtained by the application in detail of several schemes according to the particular requirements of individual houses and groups of houses, and the particular proclivities of their occupiers. My own experience tends wholly to prove that a more assured advance is obtained in the cases here contemplated by making existing and familiar local arrangements for excrement-disposal harmless, than by introducing novel arrangements. From this point of view there is no lack of means at the disposal of local authorities. If the predilection be in favour of the common privy, the Glasgow pattern (p. 162) suggests a means of diminishing its evils. Better still, Mr. Neville-Grenville has shown at Butleigh (p. 166) that it is quite practicable by a transformation of the common privy, of the simplest character, to make it an effectual and inoffensive dry-ash or dry-earth closet; and Dr. C. E. Saunders, has adopted at Tring (p. 170), a modification, hardly less simple for the same purpose. Again, Mr. Fox, at Cockermouth (p. 193), finds that it is possible to obtain the benefits of a pail system among certain classes of the rural population, irrespective of the local authority undertaking its management; and the Nottingham moveable middenstead suggests an adaptation of the pail system to rural life which must be obvious. Excellent illustrations of the advantage of such a form of middenstead I saw in operation in one instance among the fishing population of Mousehole, near Penzance, and in other instances among the agricultural population of Paul Church Town, also near Penzance. The dry-ash closets, designed by Dr. Francis T. Bond (p. 167), the simple dry-ash arrangement of Mr. Fox, and the still simpler arrangement of Mr. Neville-Grenville, are examples of a mode of excrement-disposal of which the applicability is only now being tested. Again the dry-earth system furnishes another important and extensively applicable means.

The different modes of excrement-disposal here suggested will very largely meet local needs, and the principles upon which they are founded admit of great variety in application. Ingenuity is not yet exhausted in devising methods for preventing deposited excrement fouling either the soil or the atmosphere, or from being offensive either to the sight or the smell; and local ingenuity should be exercised in planning the means of meeting these requirements for local wants. But no

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amount of ingenuity will obviate the necessity for supervision on the part of the sanitary authority; and any plan will, as a rule, certainly fail if care be not taken, in the first instance, to secure its proper application and to familiarize its use.

Excrement Disposal in Rural Districts.

Suggestions for abating nuisance from liquid house-refuse in rural districts, the complement of the abatement of excrement nuisance, are given in the report (p. 229).

V.—Summary of Conclusions.

The general conclusions which I have to submit as resulting from this inquiry, are the same as those submitted by Dr. Buchanan and myself in 1869, modified only in phraseology to meet certain modifications of details:

1. Excrement may be removed from a town or village and disposed of on more than one principle, and the same principle does not need to be applied in all quarters of the same place.

2. As regards the parts of a town or village inhabited by the poorer classes, a watercloset system may be managed so as to be entirely applicable to the circumstances of the most ignorant and most careless population. Essential conditions of such applicability, however, are that the structural arrangements should be adapted to their purpose, and that the management should be wholly undertaken and efficiently done by the servants of the sanitary authority. Where these conditions are observed as thoroughly as they are observed in parts of Liverpool and Bristol, waterclosets are the best means of removing excremental matters from the poor neighbourhoods of a town.

3. The dry-earth system affords a second way of safely disposing of excrement. It is an essential element in this system also, as applied in poor neighbourhoods, that the entire management of it shall be conducted by the sanitary authority.

4. The charcoal system affords a third way of safely disposing of excrement, subject to the same condition of management by the sanitary authority in its application to poor neighbourhoods as the dry-earth system.

4. The midden system may be modified so as greatly to reduce nuisance and danger from it. The forms of midden-closet have been described which present fewest objections. Satisfactory safety in the use of even these forms of midden-closet cannot be averred with certainty, partly because there is no near prospect of such closets being emptied daily, and partly because the materials of the middenstead would probably be retentive of some excremental matters. But if, under certain circumstances, midden-closets constructed as above should be tolerated, it would be scarcely less than essential, first, that they should, if in a densely populated neighbourhood, be emptied daily, or under other circumstances at least once a week, and secondly, that the arrangements for excrement-removal should be wholly in the hands of efficient persons appointed by the sanitary authority.

5. The pail system presents several advantages for poor town districts. This system involves construction or constructive alterations similar to those required for the toleration of a midden system, and offers peculiar advantages over the latter in regard to facility for frequent removal of excrement and to completeness of such removal, in regard to safety from nuisance, and probably in regard to profit in disposing of excrement as manure. The pails, of defined construction, should be changed daily for fresh ones in all crowded neighbourhoods and when used by several families in common or by numerous individuals, and under no circumstances should they remain unchanged more than one week. It is essential to the proper working of a pail-

system that it should be carried out in towns and villages by the sanitary authority.

6. Those who use the closet may, both under the pail and the midden system, be expected, with due superintendence, to do the cleansing of it so far as merely affects ordinary comfort and decency; but such action as concerns the effectiveness of the closet as a means of excrement-removal must be taken by the sanitary authority itself.

7. If these conclusions be accepted, it follows that there are various methods which will fairly answer the purpose of preventing nuisance and injury to health from the retention of excrement near dwellings.

B.—Detailed Report.

I.—Towns and Villages Visited and Reported on.

(*a*) *Alphabetically arranged.*

(*b.*) *Classified with reference to the particular object for which visited; the typical examples being given first in each class:*

Excrement Disposal by Cartage.

1. *Excrement Disposal without Closet.*

Edinburgh.

Edinburgh.—In Edinburgh the cleansing operations of the Corporation are designed to compass a daily removal of all filth. With regard to excrement disposal, this, in 1873, was provided for in 27,294 of the 41,615 houses* in the burgh by waterclosets, and in the remaining 14,319 houses by the scavenger. These latter houses include the tenements* of old Edinburgh, of which the common stair with the numerous apartments or suites of apartments opening upon it, occupied by separate families, may be compared to a blind court with its closeness and darkness exaggerated to the utmost. In these tenements, partly from their structure and partly from the class of people occupying them, it has been found impracticable to introduce waterclosets or other fixed method for disposing of excremental matters; and these matters as well as the dry household refuse of the tenements are systematically removed by the scavengers. The manner in which this is effected is similar to that which is enforced for dry household refuse of all kinds. "Dust carts," so called, traverse the streets of the burgh in regular beats at stated times every morning except Sundays, beginning their rounds at 6 a.m. or 7 a.m. according to the period of the year. The house refuse is removed from the new town during the first hour the carts are on duty, and from the old town during the second hour. Householders are required to take "every offensive matter" to the streets or courts "in "pails or buckets, or other proper vessels, before the time of passing of "the dust cart for deposit in it, under a penalty of 40*s*. for neglect of "this duty." In the new town the "offensive matter" removed consists of the ashes and ordinary day refuse of a household; in the old town it includes largely excrement also. The vessels containing simple household refuse are, as commonly obtains in the new town, placed on the edge of the footway and are emptied by the scavengers directly into the dust cart; the vessels containing excrement and house refuse, as largely obtains in the old town, are first emptied into the channel by the persons to whom they belong, forming more or less offensive heaps which are shovelled by the scavenger into the dust cart. This differenee in practice appears to be necessary in order to secure a proper return of the vessels, in the latter case, to their respective owners, and to prevent confusion of ownership; the police regulations requiring that these vessels be removed within 15 minutes after the dust cart has passed, under a penalty not exceeding 10*s*. for neglect.

The vessels used for both excrement and house refuse, and which do not appear to receive any other cleansing than the daily emptying, are of necessity kept by their possessors in the passage to their rooms, or in a closet, or even in the living or sleeping room.

The scavengers commence their work an hour before the dust carts commence their rounds to prepare for them, and they continue at work with one hour's interval until 4 p.m. Scavengers with barrows follow the dust carts to remove any scattered refuse which may have been left, and this is deposited in fixed dustbins until the carts next pass. Freshly slaked lime is freely sprinkled wherever filth has been deposited in the streets, courts, and thoroughfares. Twice in the week, on the evenings of Friday and Saturday, a supplementary round is made by the

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* The words houses and tenements are here used in the Scottish sense; the *house* meaning a dwelling of one or more apartments, entered by a separate door from the street, court, lane, or common stair; the *tenement*, a separate building standing by itself, or divided from others by a wall from basement to roof.

dust carts in certain streets of the old town, beginning at 9 o'clock, and the scavengers accompanying the carts are on duty one hour. Formerly this supplementary scavenging was carried out five evenings in the week, but in consequence of recent great increase in the wages of the carters it has been found advisable to diminish the number of evening cleansings. On Sunday the scavengers are on duty from 6 a.m. to 9 a.m.

The provision for excrement disposal among the tenement houses in the old town above described, is supplemented by public privies. These are 25 in number, all adapted for several persons, and some forming considerable blocks of building, with numerous seats. The greater number of these are MacFarlane's trough latrines, used without water; some are simple pail closets; and others, also pail closets, are arranged to be worked on the dry-earth system, and are now worked provisionally with dry ashes (see *Plates* I. II. III. IV.). Six blocks of privies have been fitted up on this latter plan, the scavenger of the locality in which they are placed being made responsible for their due working. The mechanism for casting the ashes or earth from the hopper upon the excrement is arranged to be worked only from the scavenger's passage in the privy, and he is expected to visit the privy three or four times daily to put the mechanism in action. This duty, however, did not appear to be well carried out; and it is probable that its efficient execution will not be ensured until one or more persons are specially appointed to attend to it. The contents of all the public privies are removed daily; the value of the excrement in adding to the worth of the general town refuse as a manure being held as a sufficient set off for their somewhat complicated arrangement and working as compared with water latrines.

The quantity of refuse carted to the depôts in 1873 was 56,000 tons, averaging a little over 150 tons daily. At a depôt on the canal, which I visited, the refuse is at once tilted into barges, and these when filled are forthwith sent into the country. At another depôt, which I did not think it necessary to visit, the refuse is stored until required by farmers. The selling price of the refuse at the time of my visit, and after it had been enriched by the refuse from the slaughter-houses and markets (which are cleansed under special regulations) and the contents of the public privies (removed daily) was 2*s*. 6*d*. per ton.

When Dr. Buchanan and I visited Edinburgh in 1869, the scavenging of the burgh was done under contract. Now the Corporation has undertaken this work itself with, it is stated, great gain both in the efficiency and economy of the work. A saving of 2,800*l*. was effected upon the cost of scavenging in 1873 as compared with 1871, the work being done better and with a smaller number of horses.

The scavenging staff and plant of the burgh are as follows:—*Staff:* 1 inspector, 1 assistant inspector, 1 general overseer, 7 district overseers, 136 scavengers, 4 depôt men, 3 cartwrights, 1 blacksmith, 2 tinsmiths, 3 shoeing smiths, 2 foremen, 2 stable men, 68 carters. *Horses*, 68. *Plant:* 36 waggons, 40 carts, 10 ordure carts, 18 water carts. Each carter is supplied with a wheelbarrow, shovel, &c., and a weekly supply of brooms. The cost of cleansing and watering the burgh for the year ending Whit-Sunday, 1873, was 21,605*l*., less 5,493*l*. obtained by the sale of manure = 16,142*l*.

No other plan probably than the plan of scavenging which has been here described, would meet the peculiar difficulties which have to be contended with in the tenements, and amidst the narrow wynds and closes of old Edinburgh and the class of population which inhabits them, and reduce the evils arising from accumulated filth there to the least practicable limits. The more closely the cleansing arrangements and opera-

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Edinburgh.

tions of Edinburgh are studied on the spot, the more forcibly is the mind impressed with the facility of dealing with common filth by systematic scavenging. The conditions, however, which determine the peculiar filthiness of parts of Edinburgh, and which have given to this filthiness historical notoriety, are happily becoming things of the past. The Corporation has entered upon and is rapidly pushing forward on the only course which will remove from Edinburgh the sanitary disadvantages under which it has so long suffered. Broad new thoroughfares are being opened out through the oldest, densest, and worst quarters of the old town, and those older tenements which have prolonged the filth and unwholesomeness of the middle ages into the 19th century, and had superadded to them the squalidness and misery of our own time, are being pulled down unsparingly. The changes which have already been effected by these clearances in the aspect of many historical wynds and closes of the old town is indescribable; and the new Old Town which is rapidly growing up in place of the old Old Town retains all the wonderful picturesqueness of that town that deserves to be retained, and will eventually add to it, while keeping little or none of its unwholesomeness. In the new tenements which have been erected waterclosets have been introduced, and in subsequent buildings the watercloset system of excrement disposal will be adhered to. But for some time to come the old tenements of the city will have to be dealt with each upon its own merits as respects such disposal, and no uniform system will be practicable.

2. *Excrement Disposal by Midden Closets and Dry-Earth Closets.*

Hull.

HULL.—Hull retains unchanged the peculiar system of excrement disposal described by Dr. Buchanan and myself in 1869. This system, supplemented in the better classes of houses by waterclosets, is now in general use throughout the borough. It rests upon a certain frequency of scavenging, the common privy being so modified in size of receptacle that it will not admit of a greater collection of excrement and dry-house refuse than that which accumulates in the intervals of the scavengers' call, and in structure that rain is excluded and soakage into the ground prevented.

For the purpose of "nightsoil collection" the borough is divided into 48 districts, each containing from 300 to 700 houses, the total number of houses enumerated for the purposes of this collection in 1873 being 30,977. The collection is carried out by the sanitary authority through the agency of contractors. As a rule each district is let out to a separate contractor, and no contractor is allowed to undertake more than two districts. The smaller districts are so arranged that the collection may be carried out by anyone who has the command of a horse and cart, and who can have the assistance of a boy or two. With a view of obviating undue combination among the contractors, and diminishing the evil effects of strikes among the men, the contracts are so timed in the letting that only 8 or 9 can fall vacant together. The contractor, in addition to receiving the material he collects, and which he sells for such profit as he can obtain, is paid by the sanitary authority from 2*s.* to 3*s.* yearly for each house in his district.* The sanitary authority provides places of deposit (four in number) where the contractor can store the collected material until disposed of; and he is subject to penalty if he should deposit such material elsewhere without permission of the inspector of nuisances in writing.

* In 1869 this payment was from 1*s.* to 1*s.* 6*d.*

The contractor is required by the terms of his contract to collect and remove, *at least once a week*, all nightsoil, offal, dry and liquid filth, dust, paper, and other refuse of every description from all premises, middensteads, ash pits, dust boxes, cellars, or other places used for such refuse, attached to all houses, shops, warehouses, yards, and other premises within his district, with the exception of trade refuse exceeding in quantity three cubic feet in any one week, and all contents of cess-pools, blood, manure, and filth from slaughter-houses, ashes from furnaces, and refuse from manufacturing processes. The work of collection and removal is to be executed on week days, from the beginning of March to the end of October between the hours of 5 and 8.30 a.m, and from the beginning of November to the end of February, between the hours of 6 and 9.30 a.m., and all carts employed in the work are to be clear of the streets and public thoroughfares, on their way to the depôts, before 9 a.m, within the former period and before 10 a.m. within the latter period. Further the contractor is required to use water-tight and properly covered carts.

In practice, while the weekly removal of excrement and dry-house refuse from the different houses in the borough is very generally secured, certain irregularities of collection are occasioned by the early hours at which the collection commences. Many families at this hour have not left their beds, and the scavenger is unable to obtain access to their premises. In these cases the families will not disturb themselves to admit the scavenger until their receptacles are full, but in regard to privies these from their construction rarely admit of more than a fortnight's accumulation of excrement and house refuse. The requirement of the contract as to water-tight and covered carts is not carried out, and the contractors are permitted to use the common open cart. It has not been found practicable to insist upon this requirement with numerous small contractors.

Consistently with the design of this plan of scavenging, and as part of the scheme it involved of preventing the accumulation of refuse matters on any premises for longer periods than one week, the common privy has been modified in arrangement, so that the pit will not hold more than a week's collection of excrement and dry house refuse. Its construction is also so altered that wetness of contents is intended to be avoided, and if wetness happens, soakage into the soil prevented.

The arrangement of this privy is shown in Plate V. The space under the seat forms the entire receptacle for all the ashes, refuse, and excrement of the house, and is built of bricks in cement, with a bottom of brick or flag, sloping from the level of the paved floor in front to a little below the ground level at the back, and forming only a very shallow pit. Into this space, through the hole in the privy seat, all dry refuse is thrown. The front of the midden space is formed by the front board of the closet, which is made moveable to give the scavenger access to the pit. There is no drain to it, as rain is excluded and slops are in practice thrown down the drains. The ashes are usually sufficient in quantity to soak up all moisture passing into the pit, and the contents are almost invariably dry, and are removed by a spade without difficulty.

The cost of erecting a privy of this construction is 3*l.*, and when built in a corner against existing walls, 2*l.* 10*s.* Every new house, if it have not a watercloset, is required to have a privy of the construction described; and at the back of every new house there must be a space of the full width of the house, and not less than 8 feet long. Upon this space only the pantry, coal-house, and privy may be placed, the privy being farthest from the house. In this way an open yard space is secured of not less than 60 or 70 square feet (see Plate V.) It is an exception to have a back entrance to this yard, and the contents of the

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Hull.

privies when removed, must, as a common rule, be carried through the house. Little offence appears to be occasioned by this objectionable arrangement, and such rare complaint as came to my knowledge referred to careless scattering by the scavenger of ashes from the bucket or other vessel in which the contents of the privy were removed to the cart.

An extended examination of privies of the kind here described, and of the manner of cleansing them, confirmed the opinion formed by Dr. Buchanan and myself with regard to them in 1869. They represent an enormous gain upon the old form of privy for which they have been substituted, both as to freedom from, and as to liability to, nuisance. In the greater number of instances inspected the excrement, even in families having young children, was as a rule well covered with ashes, and the freedom from privy smell was remarkable; and this although I had inspected on days fixed for removal of the refuse (the seventh day of accumulation), or, sometimes, in cases specially sought out, when the removal had been delayed for longer periods. The contents of the privy were dry, and their disturbance by the spade of the scavenger during removal gave rise to very little and at times to no offensive odour. In other instances privy stink was considerable, and this appeared to be determined by one or other of the following conditions :—

1. Deterioration, or original imperfect construction of the walls of the privy pit, leading to retention of portions, and perhaps to some soakage of decomposing filth.

2. Careless casting of slops into the privy pit, facilitating decomposition of the contents and soakage of the woodwork.

3. Want of adaptation of the scavenging to the needs of particular localities and their inhabitants. In the localities occupied by the most impoverished and degraded of the population the privies were overflowing with filth, and most offensive. This arose mainly from the insufficiency of the scavenging. Designed to meet the requirements of a single family only, the Hull privy cannot be used by several families without being productive of nuisance, except on condition of a more frequent removal of its contents than once a week. A daily removal is necessary under these circumstances; and as to orderliness of the privy, in those cases where a single family cannot be made responsible for it, this will not as a rule be secured unless the sanitary authority itself undertakes the duty of maintaining it.

The collection of nightsoil and household refuse is not carried out with the same efficiency in all the collecting districts. From the impracticability of exercising thorough control over the numerous contractors, the regulations for their guidance are not as carefully observed as they might be. Forty-two fines were inflicted in 1873 for gross neglect of duty on the part of the contractors; and the inspector of nuisances in his report for that year observes of some of the contractors, who do not employ suitable men, and whose horses and carts are not good, that they are "a cause of many complaints by the public," and a source of annoyance to the sanitary committee. The medical officer of health for the borough, Mr. J. Fearne Holden, in his report for the same year, expresses the opinion that the "collection of nightsoil can only be efficiently effected by the (Local) Board assuming the entire responsibility without the intervention of contractors."

Glasgow.

Glasgow.—Three different methods of excrement disposal are in use in Glasgow, besides certain experimental methods. The methods in ordinary use are (1) waterclosets; (2) pail closets; and (3) midden-closets of various descriptions. These several methods are distributed

among the 100,000 houses in the parliamentary burgh in the following numbers: waterclosets, 31,927; pail closets, 4,365; midden closets, blocks of, 1,278.* What proportion of the half million population of the burgh uses each method is not accurately known; but, in evidence before the Rivers Pollution Commission in 1870, Mr. Carrick, the master of works, stated that about half the population used waterclosets. A pail, in a pailcloset, is considered to be necessary for every 10 families; a privy may serve for many more families, as in some of the instances which will presently be referred to. In one of these a privy serves for 59 families. This, however, is not considered adequate accommodation.

In Glasgow, as in Edinburgh, the tendency in new buildings is to

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* Parliamentary Burgh of Glasgow, 1872–3.

Return showing the Number of Houses, Manufactories, Shops, Warehouses, Drains, Ashpits, and Waterclosets, &c.

Number of dwelling houses		101,368
" shops		8,874
" warehouses and counting-houses		4,053
" manufactories and workshops		3,291
" stables		2,304
" horses		7,024
" cowhouses		311
" cows		1,350
" urinals drained into sewers		211
" ashpits drained	5,288	
" " undrained	795	
		6,083
" privies drained	935	
" " undrained	343	
		1,278
" pans only		4,365
" common sewers, lineal extent in yards		140,366
" manufactories discharging organic refuse	55	
" " " chemical "	54	
		109
" waterclosets in houses of one apartment	454	
" " " two apartments	5,702	
" " " three " and upwards	21,512	
" " " in shops	1,709	
" " " " warehouses, counting-houses, &c.	2,550	
Total number of waterclosets in the city		31,927
Number of sinks in houses of one apartment	11,185	
" " " two apartments	30,502	
" " " three " and upwards	29,604	
Total number of sinks in the city		71,291
" fixed basins in dwelling houses		3,865
" cisterns for W.C. and domestic supply	8,940	
" " " only	14,957	
		23,897
" houses supplied with water from mains	55,394	
" " " " cisterns	31,802	
		87,196
" soil pipes, ventilated	17,701	
" " unventilated	14,522	
		32,223
" cesspools		1,901
" courts, paved	6,444	
" " drained	8,831	
		15,275
" stairs and passages, ventilated		7,876
" dwelling houses, lobbies		92,895

	1872	1873.
Estimated Population within Municipal Boundary	502,990	514,295

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adopt waterclosets, and these are being more extensively introduced from year to year. The older tenements of Glasgow, as of Edinburgh, from their arrangement and the class of population inhabiting them, do not admit of the introduction of waterclosets. For these buildings and their inhabitants efforts are mainly directed to the improvement of previously established plans. I observed in some of the newer tenements which had been furnished with waterclosets that these were out of order and offensive. This had arisen from inability to make particular families in the common stair responsible for the cleanliness of the waterclosets, owing to the inconvenient position and insufficient number of the latter. In other instances, where each flat had its separate watercloset, and this was kept locked, the families of the flat being held responsible for its orderliness, the waterclosets were kept in excellent order, although imperfectly lighted from the common stair.

When Dr. Buchanan and I visited Glasgow in 1869, middensteads were to be seen attached both to public and private privies, of enormous size, filthy and fœtid, uncovered, receiving all urine as well as stools of the neighbourhood, and also ashes. Middensteads of this kind still exist, but probably all are now covered in. Of the 1,278 middensteads in the burgh, 935 are drained. For middensteads of this class there are now being substituted smaller, covered, undrained middensteads, of a capacity calculated to hold two days' accumulation of the filth, ashes, and dry-house refuse of the families using them. This important change, begun before 1869, has since been steadily carried out, and recently has received a further development, which makes the Glasgow midden closet, as newly designed—one detail alone excepted,—a pattern for the construction of the common privy, so long as common privies must be tolerated. The additional improvement consists in so fixing an inclined plane beneath the opening through which the ashes and dry-house refuse are thrown into the middenstead, that these shall fall above and cover the excrement. The exception referred to is that the bottom of the middenstead is sunk beneath the level of the ground, which should not be the case. Mr. Carrick, the master of works, appears to have been the first to have conceived this arrangement, but its successful working out has been due to Mr. Dobson, of the sanitary department. Plates VI. and VII. show the arrangements of this form of privy.* The following description of the plans, including also a description of a plan of pail closet (Plate VIII.) is furnished by the sanitary department:—

Description of Privies in the Central Sanitary District of Glasgow.

No. 1 (*Plate* VI.)—Is a combined ash-bin and privy, constructed with 9-inch brick walls, the seat, riser, inclined plane, bottom and roof of 1¾-inch Caithness stone. The whole structure covers an area of 56 superficial feet. This gives accommodation to 27 families, two warehouses, and seven shops, and costs 16*l.*

No. 2 (*Plate* VII.)—Is a design of two privies, placed back to back, and divided into four compartments by two partitions of Caithness stone, 2½ inches thick; the external walls are built of 9-inch brickwork in mortar, the seat, riser, inclined planes, and bottom of bin of 2½-inch Caithness stone set on one course of brick footings.

The dotted lines are suggestive of a screen to hide the persons sitting from persons passing. The superficial area on which it stands is 95 feet, and giving accommodation to three distinct localities, having a population of 236.

No. 3 (*Plate* VIII.) is the plan of a privy on the pan system, constructed with 1¾-inch Caithness paving stone set in grooves in the pavement of the court,

* Mr. Dobson has also devised an ingenious mechanical arrangement, the details of which are shown on Plate VIIa., having for object the prevention of annoyance, from ashes being cast into the middenstead when in use, to the persons using it. An experimental trial of this arrangement was being made when I visited Glasgow.

and cramped together with $1\frac{1}{2}$-inch × $\frac{3}{8}$-inch wrought iron angle irons, and $2\frac{1}{2}$ × $\frac{1}{2}$-inch screwed bolts and nuts jointed neatly with Portland cement, adapted for the accommodation of males, females, and children.

The seats are made of cast-iron with close-fitting galvanized iron pails underneath. The whole structure covers an area of 65 superficial feet, accommodating 59 families, and cost 16*l.*

The objection to this privy arises chiefly from the foul odour continually emitted from the coating of fæcal matter on pails, which could easily be obviated by substituting a clean, disinfected pail at each removal. [The contents of the pails are merely emptied into the scavengers' cart without other cleansing].

At the time of my inspection there was superabundant evidence in the central district, from overfull middensteads and ash-pits, that the operations of the sanitary department and of the scavenging department were not in proper accord. The scavenging of the middensteads and ash-pits has not kept pace with the work of the sanitary department in reducing their size, and as a consequence of the less capacity of these receptacles, they fill and overflow more rapidly than the scavenging department is prepared to deal with them. This want of accord between the two departments did not seem to me to rest upon any necessity of the case, but to arise chiefly from the vicious principle upon which the scavenging of the middensteads and ash-pits is carried out. Theoretically the central district of the town is scavenged every alternate night, and in practice the nightsoil carts traverse it for this purpose. If the scavenging were carried out systematically from street to street, privy to privy, and ash-pit to ash-pit, the present arrangements would suffice, no doubt, to obviate the nuisance from overflowing middensteads and ash-pits which came under my observation. But actually the scavenging is governed by the fullness or not of the middensteads and ash-pits, and this in a given locality is judged by the largest not the smallest. The same practice holds good in the scavenging at longer intervals of other districts of the city. The mode of payment of the scavengers directly fosters this practice, and holds out a premium for imperfect work in another important way. The scavengers are paid at so much per ton of the filth removed, and it is to their interest to encourage fulness of the receptacles so as to diminish the quantity of ground traversed in collecting the contents.* Another evil of this mode of payment is, as I had occasion to observe, that it affords an inducement to the men to cleanse the receptacles imperfectly, the walls not being scraped and the bottoms carefully swept out.

Plate VIII. gives a drawing of a pail closet in ordinary use for a court or common stair. The pails are galvanized iron cylindrical vessels, calculated each to serve for 10 families during the intervals of the scavengers' rounds. These pails, which receive excrement only, are simply emptied into the scavengers' cart, and are neither scraped nor otherwise cleansed. The whole of those I saw were encrusted with filth, and stank offensively, and Dr. Russell, the medical officer of health, has satisfied himself that the excremental matters received into them when in this state rapidly decompose.

The ash-pits, or more accurately middensteads, attached to these pail-closets also receive a considerable quantity of excremental matters from chamber-pots, which are freely used for defæcation in the tenements, and of which the contents are not uncommonly retained some time in the house.

* "Under the present system the men work by the ton, and could not under the nightly system earn the same amount of wages, as they would require to travel over much more ground before they could collect the same quantity of material."—*Observations of the Inspector of Cleansing in reference to a Memorandum of the Medical Officer of Health on the system of cleansing ash-pits, pans, &c.*, 17*th July* 1873.

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Dr. Russell has made the following suggestions as to the scavenging of middensteads and privy-pans :—

" 1st. Every midden receiving human excrement should be emptied daily, the only open question being whether in the winter season, when decomposition takes place more slowly, two or three days might elapse where the size and position of the midden will admit.

" 2nd. Every privy-pan should be emptied daily, and in confined localities, during the prevalence of specific diarrhœal disease, twice daily.

" Following these main propositions, and carrying out the principle into details, it may be added :—

" 1st. That after emptying a midden, the close, court, street, or other surface smeared with its contents should be carefully washed with the hose before the heat has converted the matter into dust, which, as well as the gases evolved, may be transported by the air.

" 2nd. Pains should be taken actually to empty the midden, and to scrape from its sides all adherent dirt.

" 3rd. The privy-pans should be not only emptied, but cleaned, so that they may not be replaced having a layer of fæcal matter over their sides exposing a large decomposing surface to the air, and ready to act like a ferment on the fresh excrement, rapidly propagating to it the process of decomposition.

" 4th. Another matter indirectly coming up for remark in this connexion is the removal from the roofs of privies, and other out-houses, of the organic matter thrown there from higher levels. The prevention and punishment of this offence is desirable, but meanwhile, and especially in hot weather, those decomposing matters ought to be removed."

Under existing arrangements, Glasgow for the purpose of scavenging is divided into six districts. The scavenging of the privies and ash-pits is carried out between the hours of 11 p.m. and 8 a.m., and the night staff consists of 65 carts and men with 60 emptiers. The quantity of stuff removed by this staff per week to the various depôts, 10 in number, is computed at 2,000 tons, where it commands a sale for manure at 1*s.* 6*d.* per ton, The entire cost of the scavenging department for the year 1872–73 was 46,275*l.* 0*s.* 0*d.* with a set-off for sale of manure and other items of 17,493*l.* 0*s.* 0*d.* The sale of manure for the year had produced 17,987*l.* 0*s.* 0*d.*; the receipts for manure, including outstanding sums for the preceding year, were 17,375*l.* The scavenging is done by the Corporation, and here, as in Edinburgh, the statement is made very positively that the Corporation to secure the same degree of efficiency does the work with its own staff and plant at a less cost than it could be done by contract.

Two experimental methods of excrement disposal came under observation in Glasgow, one a modification of the watercloset system (*Hoey's watercloset*) ; the other a system in which charcoal is used to deodorize the excrement and facilitate its ulterior use. This last-named method I have had to examine elsewhere than in Glasgow, and the illustrations of its operations I observed in this city I have included in the separate description which I have given of the method.

Hoey's watercloset is designed to limit to the smallest amount consistent with efficiency the quantity of water used in flushing the pan, and to prevent the passage of the excrement into the sewers. An ingenious arrangement in the cistern restricts the flush of water to a fifth of a gallon, and the excrement is received into an iron tank beneath the floor of the building. By diminishing the amount of the water with the excrement a manure of commercial value sufficient to cover the cost of this arrangement is believed to be obtained; by keeping the excrement from the sewers the dangers commonly arising from sewer air are supposed to be avoided. The tank when full is emptied by atmospheric pressure into an exhausted wheeled

receptacle. I examined this arrangement as applied to four closets in tenement No. 243, Stirling Road. In each closet on raising the handle there was a mere dribble of water, in quantity quite insufficient to remove freely and fully an ordinary stool, especially with paper, and the closets had to be flushed from time to time with a bucket of slops or of water. Each closet pan, although the closets were locked and under the care of orderly people, was more or less smeared with excrement. The excrement tank is a cesspool, and the protection from it on the house side, supposed to be obtained (if the arrangement be adopted, which was not the case so far I understood at No. 243 Stirling Road) by a disinfecting cistern, which suffers a charge of a disinfectant to pass into the soil pipe with each use of the closet, is simply fallacious. Even more fallacious is the supposition that the tank intercepts the passage of the whole of the excrement into the sewers. The tank has an overflow, and there was no certainty in the instance under observation that the overflow was not in frequent action. The tank, in fact, is a mere catch-pit interposed between the soil pipes and the sewers. The whole arrangement is such as to demand for its reasonable working an amount of supervision rarely possible to obtain; and the advantages claimed for it in saving water and securing a saleable manure appear to me to be gained at the cost of more important considerations.

Note.—Through the kindness of Dr. A. Fergus, I had an opportunity of examining during my visit to Glasgow several examples of corroded and perforated soil pipes. Dr. Fergus discovered these perforations in soil pipes a few years ago, and his subsequent observations have led him to the conclusion that they are an occasional important source of unsuspected sewer air pollution of the interior of houses, and the pathological consequences thereof. He has found them especially co-existent with enteric fever and diphtheria where complete freedom from chances of sewer air poisoning was believed to exist. The corrosions and perforations were most frequently observed in the upper extremity of the pipe, and if there were a bend or arch in it on the upper portion of the bend. The corrosions invariably proceeded from within outwards. Dr. Fergus has the following observations on this subject in a pamphlet he has published on "*The Sewage Question: with special reference to traps and pipes.*" (Glasgow, Porteous, Brothers, 1874):—

"Lead has generally been used as the material for soil pipes, and as we have seen how capable it is of corrosion, it becomes a very important sanitary question to inquire how long a good lead soil pipe will hold out. I have been studying this question for years, and it is now about seven years since I first exhibited decayed pipes in public, yet, I would not wish to dogmatize on the subject, but rather give approximations, and would remark that the time will vary under the various circumstances according to the strength and rapidity of the flow of the sewage, as well as the original thickness of the pipe. But after allowing for this, we must broadly distinguish between soil pipes which are ventilated and those which are not. By the former I mean when the pipe is carried up to the roof of the house and open to the external air; by the latter, I mean when the pipes are closed up. Of these last-mentioned, the duration may be stated to be about 12 years, the extremes of variation being from a minimum of 8 to a maximum of 20 years. In ventilated pipes the duration may be stated to be nearly double, running from 21 to 33 years, the extremes of variation being from 18 to 30 or even more years. The practical sanitary conclusion which it concerns us all to keep in mind is, that any house, no matter how carefully or well built, may become unhealthy from this source, and that when cases of typhoid fever, diphtheria, &c. occur, the pipes should be thoroughly inspected, especially their upper surface, and the whole of the soil pipe uncovered. I must strongly insist on this, as in many cases the plumbers have declared pipes to be all right, which turned out to be very defective when uncovered. For some years back, I have insisted on a careful

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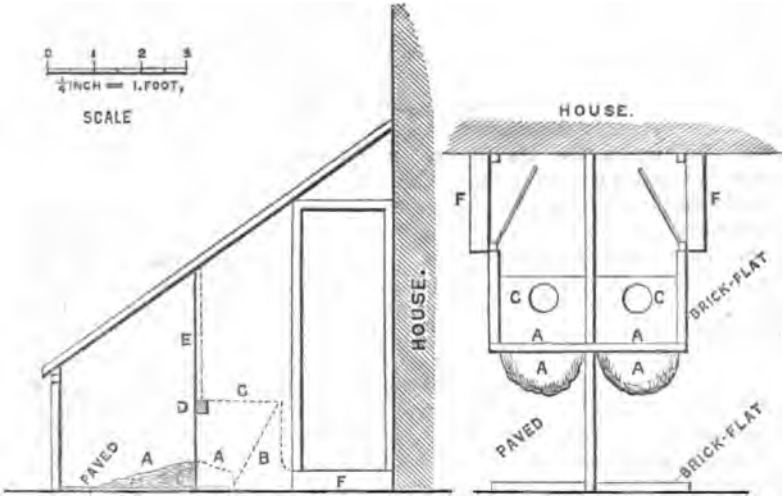
examination of the soil pipes wherever I have cases of typhoid or diphtheria, and in every case where I could get this carefully carried out, I have detected these perforated pipes, or sewer air getting into the houses in some other way," (p. 21).

Butleigh.

BUTLEIGH (*Somerset*).—I had an opportunity of examining at Butleigh an improved privy which Ralph Neville-Grenville, Esq., M.P., is introducing among his cottages. This privy is most instructive as showing by what simple means the abounding nuisance of the common privy, and the indecency connected therewith, which too commonly exists in rural districts may be often got rid of. The change Mr. Neville-Grenville has effected from the old-fashioned privy is shown in the accompanying drawing (Fig. 1.), copied from an article by him on "Cottages" in the *Journal of the Bath and West of England (Agricultural) Society* for 1873.

Fig. 1.



A. Heap of dry earth or ashes in open shed.
B. A stone slab.
C. Seat.
D. Joist on which rests the brick or lath-and-plaster wall, E.
F. Step.

Below the joist D the privy-pit is open, admitting of the soil being covered from behind; or a shovelful of dry earth or ashes may be thrown upon the soil through the opening in the privy seat.

This change consists in filling up the middenstead to the level of the surface of the ground and paving the filled area, extending the roof of the closet so as to cover this, raising the closet floor a step, and with it the closet seat, and placing a flag sloping backwards beneath the seat so as to diminish the space there and place the excrement in a better position for the treatment now to be described. The roofed space in rear of the closet, the area of the former middenstead, is left open on the side of approach, and is used for the deposit of the ashes, and these failing for a deposit of dry earth. The cinders are separated from the fine ash by a common riddle, the former for re-burning, the latter for covering the excrement, and if the fine ash should be insufficient dry earth is applied: or both fine ash and dry earth are used together. I examined several of the improved privies, and in every instance but one found the excrement fully covered and an absence of all offensive odour; a slight odour in the excepted instance arising from imperfect application of the fine ash. The efficiency of Mr. Neville-Grenville's arrangement equals its

simplicity; and it was noticeable how more decent privy arrangements had begotten a greater care for the orderliness of the privy and its vicinity. In one instance, the opening to the space behind the closet was closed by a neatly constructed screen of straw.

Bradford.

Bradford, *Yorkshire* (1871, population, 145,830; inhabited houses, 29,408).—In 1872 I had to report on the state of middenstead nuisance in Bradford among other sanitary defects of that town. The Corporation has recently approved a form of midden-closet, which, while presenting certain improvements upon the old-fashioned midden-closet, has defects so grave that it is desirable to note them here for the sake of warning. The approved midden-closet is directed to be constructed according to the following instructions:—

"The foul earth under the old privies and ashpits to be entirely taken out and at once carted away, and the old ashpits to be filled in with concrete.

"The privies are to be built in the manner and form, and to the dimensions shown in the detail drawing. (*See* Plate IX).

"The ashpit to be sunk four inches below the sill of the emptying door, and the bottom to be flagged and made watertight, and laid with an inclination of not less than nine inches from the door towards the back or shallow end of the ashpit.

"Across each ashpit there must be a grating fixed in such position as shown in the detail drawing.

"Each privy and ashpit to be covered with large Yorkshire flags or landings.

"The upper door of the ashpit to be provided with a thumb latch, as shown in the detail drawing, and the lower door of the ashpit to be provided with a catch-lock, capable of being opened with an ordinary railway carriage key.

"The whole of the works are to be executed in a good and workmanlike manner."

The grating approved at the time of my recent visit to the town was formed of stout iron wire with a 2-inches mesh.

I visited several blocks of privies which had been erected in accordance with this plan, and found in each instance the grid loaded with a foul mass of ashes and house refuse; and such ashes as had passed through lay in a heap beneath the grid and between the deposits of excrement, leaving the latter quite exposed. In one instance of a block of four privies, not only was the grid laden, as described above, and the excrement exposed, but the urine and other wet in the middenstead was running from beneath the door for emptying, forming a sluggish stream to the nearest yard-gulley. The offensiveness of this block of privies was not less, if, indeed, it were not greater than that of an old-fashioned open midden-privy.

In fact, the position of the grid is such that, if the ashes be raked above it, the fine ash will not fall upon the excrement; and the capacity of the middenstead, in accordance with the arrangements for night-soil scavenging, is sufficient to hold several weeks' accumulation of ashes and excrement, while its shallowness makes necessary frequent systematic scavenging if nuisance is to be avoided.

Gloucester.

Gloucester.—At Gloucester I had an opportunity of examining two forms of Dry Closet in experimental operation which had been designed by Dr. Francis T. Bond, the medical officer of health for the Gloucestershire Combination of Sanitary Authorities, to meet certain require-

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ments of his district. One of these closets is described by Dr. Bond as the closet with "*external ash distributor,*" the other as the closet with "*internal ash distributor.*" The following diagrams, to which I attach Dr. Bond's descriptions, illustrate the arrangements of these different forms of closets. Both forms may be fitted with urine separators, but this arrangement is shown only in the diagram of the second form :—

Fig. 2.

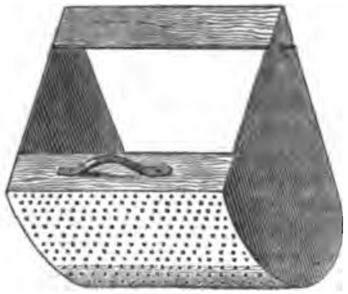
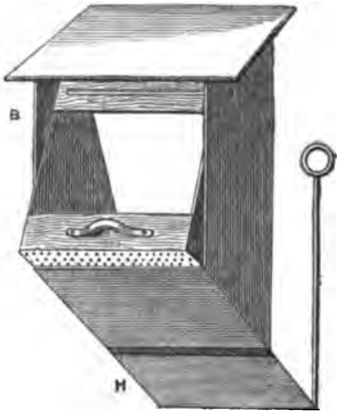


Fig. 3.



Closet with External Distributor. *Distributor* (*Figs.* 2 & 3).—G a cradle with sifting bottom suspended in a box B, which is attached to the side or back wall of the closet on the outside. At the bottom of the box is a sloping board H hinged at one end, on which the ash falls. To the other end of this board is attached a wire, the free end of which rises through the seat of the closet, so that on pulling it up by the handle which is attached to it, a jerking motion is given to the board, which shakes the ashes from it into the receptacle. The cinders are removed from the cradle by merely pulling it forward, when they fall out of it through a shoot which is placed in front of the sifter, into the coal box or other receptacle which may be placed beneath to catch them.

Fig. 4.

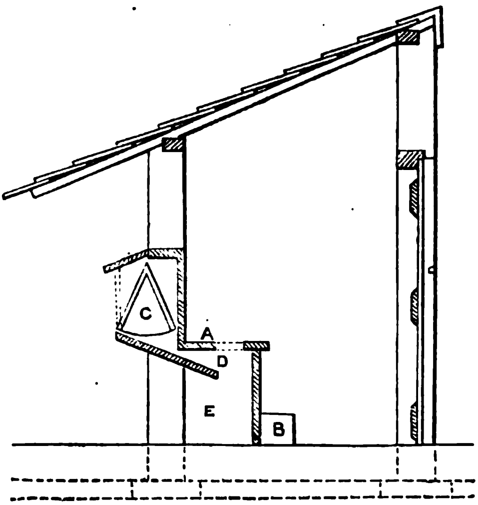


Fig. 4. *Section of Closet with External Distributor attached.*—A, seat; B, step; C, cinder sifter; D, ashes shoot; E, space for moveable receptacle.

Fig. 5.

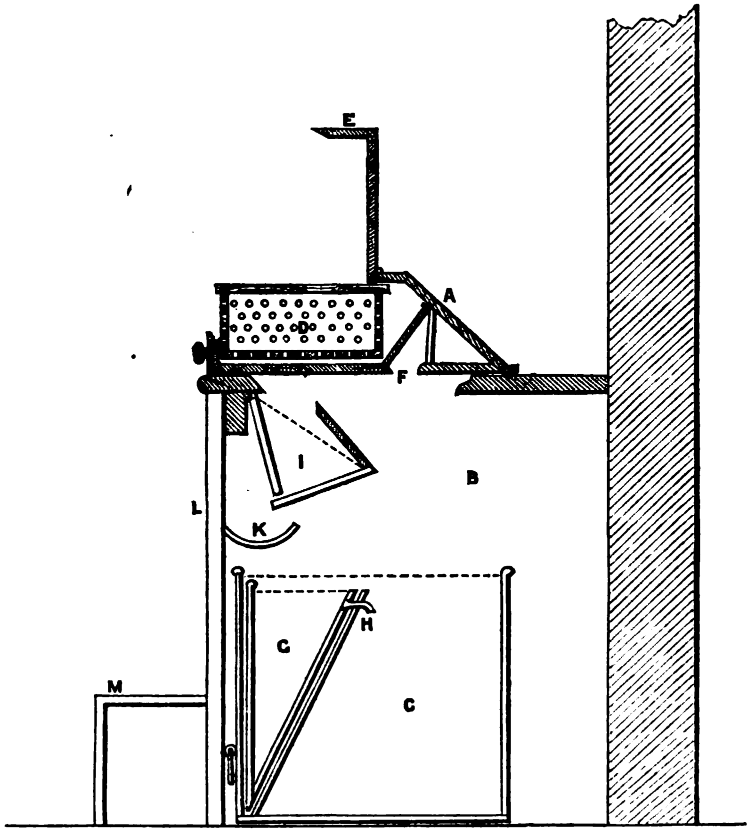


Fig. 5. *Closet with Internal Distributor.*—"A, ash-distributor with lid, E, open, showing sifter, D, inside and aperture for discharge of ash, F. In B, the space beneath the seat, is seen the receptacle C, which is a bucket specially constructed for the purpose, with a cover (to be used when the bucket is removed for cleansing), a handle at the top, and one near the bottom in front. At G is seen the urine receptacle, a separate vessel, which can be readily lifted out of the bucket by a handle on either side to allow of the contents being poured out. At H is an over-flow vent, so that in case the vessel is allowed to remain until it becomes over-full, the urine will run over into C and thus give indication of the need for attention. At I is the separator (the real shape of which cannot be represented in section), consisting of three elements intended to meet the conditions of adult males and females and children respectively. K is a gutter into which the urine passes, except where a bucket with separating vessel is used when the urine falls out of the separator into the latter. The riser of the seat, L, should in all cases be attached to the seat in such a way that it can be removed for the purpose of taking out the bucket. M is a small support for the feet which may be attached to the riser, and which is required in consequence of the increase in the height of the seat, which is necessary in order to allow of a bucket of fair size being employed.

"*Action of Apparatus.*—A person on entering the closet raises the distributor A, which then rests in the vertical position against the wall. In so doing he gives sufficient motion to the ashes inside to fill the receptacle which measures the charge. On leaving the seat he replaces the box (as he is requested to do by a notice which is fixed to it) and in so doing discharges the charge of ashes through F into C. The sifter is large enough if filled with ashes, to hold sufficient for 10 or 12 uses of the closet. Hence if properly filled it need

not, in the case of an ordinary household, be refilled more than every other day. Under similar circumstances the urine receptacle need not be emptied more than once a week, and the bucket itself more than once a fortnight. The operation of emptying the urine vessel is not more offensive than emptying an ordinary chamber pot, and the bucket itself, when full, may be carried through a house without the slightest unpleasantness being perceived.

"The dimensions of the seat, to allow of the above arrangements being adopted, should be as follows:—From before backwards not less than 20 inches, divided as follows; from front edge to front margin of hole 2½ inches, from front to back margin of hole 10½ inches, from back margin of hole to wall 7 inches.

"It is not essential that the urine should be collected in the soil bucket. It may be conducted from the separator by a piece of piping into a vessel placed outside the closet for its reception. Where this can be conveniently done it is perhaps the better plan, as any neglect to empty the vessel will be more evident and its results less offensive than when this takes place inside the closet. Or, where a drain is convenient, the urine pipe may be connected with it, and the urine got rid of in this way. Or, again, where no well is immediately near, the urine may be carried into a small covered cesspool made close to the closet."

My observations were limited to the action of the cinder-sifters in the two closets. Both forms appeared to act efficiently, but the greater complexity of the internal form will no doubt restrict its useful application as compared with the simpler external form.

At the time of my visit to Gloucester, Dr. Bond was engaged in addition to perfecting the operation of his dry-closets, in an interesting experiment on the disposal of liquid house-refuse. The experiment was too incomplete to admit of description here, but the principles upon which it was being worked out may be mentioned. Dr. Bond believes that it is quite practicable to depurate liquid house-refuse before it leaves the premises, so that what flows away shall not be productive of nuisance. This he proposes to effect by subjecting the refuse to a combined process of straining, chemical precipitation and filtration. The apparatus for the purpose consisted of an ordinary waterbutt with a simple strainer at the mouth and floating filter within. The most effective form of precipitate Dr. Bond had not fully determined at the time of my visit; but such results as he showed me of his experimental trials augured well for a successful issue. [Dr. Bond has since informed me that he has made several unessential changes in the "closet with internal distributor;" and that he has determined two available forms of precipitate. One of these which is also a deodoriser, and is believed by Dr. Bond to be a true disinfectant, is termed by him *cupralum*, and is a mixture of cupric dichromate, and aluminic sulphate with terebene.]

Tring.

Tring, Herts (1871, population 4,045; inhabited houses 850).—The urban sanitary authority of Tring has adopted at the suggestion of its medical officer of health, Dr. C. E. Saunders, a modified form of privy, of which a diagram is given in Plate IX[a]. The peculiar characteristics of this privy are a shallow pit, and a bin placed at the side of the seat, for containing dry-earth or ashes. The cottagers where this form of privy has been erected are instructed to keep the bin provided with one or other of the materials named, and after each use of the privy, to throw upon the deposited excrement a scoopful of the dry-earth or ashes. I saw several of these privies which had been some little time in use. Where reasonable attention could be secured in covering up the excrement with the earth or ashes, the freedom from nuisance was marked. In view of the necessity for frequent removal of the contents of these closets and of their storage in garden plots, it appeared to me desi-

rable, as a rule, where no proper care from the users can be reckoned upon, to have all ashes and dry household refuse thrown into the pit: to use them, in fact, as middensteads. By this simple plan there would probably be more likelihood of nuisance being avoided among the careless both in the privy and in the subsequent disposal of the contents of the pit.

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[A somewhat similar privy arrangement to the above, and method of use, has been adopted by the rural sanitary authority of St. Neots. In this form of privy, a box or scuttle to contain earth, ashes, or other deodorising material is directed to be placed upon the floor of the privy.

A completer arrangement has been designed by Dr. Baylis the medical officer of health to the West Kent combination of sanitary authorities. He provides, as in the Tring privy, for a bin attached to the seat to contain dry-earth, but a metal pail forms the excrement receptacle, and in rear of the privy he constructs a proper covered dust-bin. Into this dust-bin the contents of the pail can be deposited, along with the ashes and dry house-refuse, when they cannot be at once used for the garden.

The St. Neot's privy and Dr. Baylis' improved privy and dust-bin I have not seen in use.]

3. *Excrement Disposal by Pail-Closets.*

Rochdale.

ROCHDALE (1871, population, 64,754; inhabited houses, 13,933). — Six years ago the Rochdale Corporation undertook a twofold experiment in excrement disposal, designed to abate the nuisance from middensteads, and to put their contents to more profitable use. The experiment consisted in the conversion of a certain number of privies into pail-closets, some being managed on the Goux system, others in a simpler manner. The conversion, where accomplished, at once did away with the nuisance from middens by the destruction of the middenstead, and both methods of managing the pail-closets proved equally effective in keeping under control and in diminishing to an extremely insignificant amount, as compared with the common midden, nuisance from excrement. After several months trial the Goux system was set aside, the simpler method of managing the pail-closets adopted, and out of this simpler method has been developed that plan of dealing with the excrement and dry refuse of households known as the "Rochdale system."

A report of the sanitary committee of the Corporation, under whose supervision the pail-closet experiment had been carried out, and which was published in August 1869, stated, as reported in that year by Dr. Buchanan and myself, that in both systems of management applied to the pail-closet, "the essential condition of the trial, *frequency of re-*" *moval*, had been secured; that the system of removal had been " thoroughly approved by all who had had experience of it; and that it " had not failed under most varied conditions, having proved equally " efficacious in the highly-rented house with its own closet, in the " lodging-house where great numbers were accommodated, and in the " factory and workshop. In the subsequent manufacture of the dejec-" tions and ashes into a saleable manure, the committee concluded that " the Goux system was less advantageous than the use of tubs without " absorbent linings."

When Dr. Buchanan and I visited Rochdale in 1869, 500 midden-stead privies had been converted into pail-closets, the other arrangements for the excrement disposal of 45,000 people, occupying 9,000

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houses, consisting of 4,000 middenstead privies and 300 waterclosets. In 1872 the Borough was much enlarged, and within this extended area, at the time of my visit (September 1874), the number of pail-closets amounted to 4,397, of which upwards of 3,200 were within the limits of the Old Borough (3,250, January 1874); the estimated number of middenstead privies to 2,000; the waterclosets remaining about the same in number as in 1869.

The Rochdale system of excrement disposal consists in the systematic removal at weekly, or shorter intervals, of the excrement and dry refuse of households, the collection of the excrement and dry refuse in pails, each separate from the other, the manufacture of the excrement with fine coal ash in a particular manner into manure, and the profitable utilisation of the rest of the dry refuse.

In putting this system into force, the following rules were acted upon by the Corporation, as stated in a report published in December 1873:—

"1. That the privies to all new houses should be on the new system.

"2. That all additional privies to old property should be on the new system, and be accompanied by the alteration from the old system to the new of all existing privies to the same property.

"3. That all old privies being rebuilt should be on the new system.

"4. That the first cost of the ash tub and receptacle for the excreta should be paid by the owner."

No difficulty was found, it is stated in the report referred to, in carrying out these rules, nor has "complaint or opposition been made, "and in no case has the Corporation had to exercise any legal authority "to enforce them. This feature is, no doubt, owing to the facts that the "old form of privy and ashpit is more expensive to build than the new "one; that the privies under the new system are much more cleanly; "that from the absence of moisture they are more durable; and that "they need less repairs than those under the old system."

The progress made in the establishment of the new system from year to year is shown by the following figures:—

Rochdale System.

Year ending	No. of Privies.	
	Old Borough.	Extended Borough.
1870, March 31 -	527	—
1871, „ -	1,070	—
1872, „ -	1,690	—
1873, „ -	2,309	—
1874, January -	about 3,250	—
„ September -	—	4,397

The form of privy (closet) is not prescribed by a formal specification, but a pattern (*Plate* X.) for builders, which may be modified to suit special requirements of space, is placed in the yard of the manure works; and certain structural details are required of which I subjoin a summary.* An approved form of adaptation to new buildings is drawn

* The following is a summary of certain structural details required in pail-closets:—

Floor of privies and ashpits to be flagged with 3-inch flags; lintels to be $4\frac{1}{2} \times 3$

in *Plates* XI., XII. In the pattern it is shown that the excrement pail may be removed either at the back or side of the seat, or at the front; the seat being hinged and its front made moveable as a slide or on hinges to admit of this. The seat itself has a deep metal rim beneath the aperture for directing the urine into the pail. The building must be effectively roofed, and the floor is required to be flagged with Rochdale flags at or above the level of the court or passage; and in the case of reconstruction of middenstead privies, the middenstead must be properly filled to the same level. In certain instances of the pail-closets which came under observation, the space for the ash-tub was needlessly large, and had given occasion to some unsightly littering of dry refuse upon the floor.

Two kinds of *excrement pail* are in use, one for houses, the other for factories. The former is a wooden pail formed from the half of a disused paraffin cask, with handles attached and with lids (*Plate* XIII.). The latter is a galvanized iron pail, also with handles and lids. The wooden pail has a capacity of 100 lbs., and costs complete for use 4*s.* 9*d.* The metal pail, of larger capacity, costs 9*s.* 6*d.* The wooden pail is of the same kind as was in use in 1869, and it is still held to be more convenient and economical than a metal pail for the purpose to which it is put. The metal pail deteriorates somewhat rapidly at the bottom, and a wooden bottom is now being substituted for the metal when it needs repair. In 1869 the lid of the pail was single, and it was fixed in place so as to prevent stink being diffused from the contents during removal by an india-rubber packing. A different arrangement is now adopted, two lids being used, an inner and an outer, both resting within a groove inside the pail, the outer lid fixing the inner lid, as shown in *Plate* XIV. These lids being made of metal, I observed in a few instances that they had been battered by use out of form, and consequently did not fit into the groove of the pail as closely as was desirable.

The *ash tub* is usually a tub with handles in the form and dimensions given in *Plate* XIII. I noticed in the course of inspection that it would be well that the scavengers should be provided with the means of scraping, and have instructions to scrape such tubs as from whatever cause might be furred within.

The *removal* of the excrement pail is effected in a covered van, and of the contents of the ash tub in an open cart. Both van and dust cart differ in design from the van and dust cart used in 1869. The van (*Plates* XV., XVI.) is constructed to hold 24 excrement pails arranged in two rows, and placed within it from either side, flaps being raised for the introduction of the pail. The flaps when fastened down rest upon hollow india-rubber beading, which effectually closes the interstices between the lid and the body of the cart. The *dust cart*, which in 1869 was a covered vehicle, is now a simple open cart (*Plate* XVII.).

The arrangements for the removal of, and process of removing the excrement pails and dry house refuse are as follows:—The town is divided into six districts for the purposes of removal, and the dry house refuse is removed at the same time as the excrement, a dust cart accompanying each night-soil van for the purpose. The removal is all

spars 3 × 1½ and 16 inches, centre to centre; wall plates to be 4½ × 3; roof covered with Welsh slates 20 × 10, lap, 3 inches; ceiling of privies, lath and plaster to spars; urine flags to be 1½ inches thick; seats 1¼, nosed and fixed on bearers; door frames, 4½ × 3, wrot., rebated, and chamfered; doors, 1 inch, and edges 7 × 1¼, T hinges, and secured with latch and catch; each door to have lock and keys; wood gutter, 6 × 4, with 2 inches down-spout, head, &c.; iron conductors to be fixed under privy-seat.

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effected during the ordinary working hours of the day, the vans commencing their rounds at 7.0 a.m., and ending at 5.30 p.m. Each night-soil van makes five rounds daily. It leaves the yard laden with clean empty pails, each pail containing a quantity of a "disinfectant," and returns carrying the pails containing excrement, for which the empty pails have been substituted. The process of substitution is effected by the scavengers withdrawing from beneath the closet seat the pail containing excrement, covering this up with the lids already described, removing it to the van, an empty pail being left in its place, and on placing the pail in the van sprinkling over the outer lid a little carbolate of lime. The ash tub is then carried to the dust cart and its contents simply tilted into it. Each pail closet is numbered and registered, and the scavengers proceed from closet to closet systematically, according to the portion of their district within the day's beat, revisiting at the end of each round the closets from which the pails had been removed, and those, if any, which had been omitted. The greatest number of omissions for any one month in the whole town has been 42, for any one week 14. Each Monday the scavengers' returns are balanced, and a supplementary van with dust cart sent out to rectify omissions. In the case of lodging houses and closets used by several families the excrement pails are removed twice or thrice weekly.

On the return of the vans and dust carts to the yard, the collections of excrement and dry house refuse are immediately dealt with. The contents of the ash tubs are screened by machinery, to separate the fine coal-ash from the cinders and other refuse. The cinders are then set aside for use in the furnaces and for sale, the refuse metal, leather, and rags are sold, and the vegetable refuse burnt. The fine coal-ash is used in the process of manure manufacture. Deposited on the floor of sheds trenches are made in it, and into these trenches the contents of the excrement pails are poured as received. The excrement is then covered with fine ash, and a quantity of sulphuric acid is added to facilitate drying. At intervals of about seven days other excrement is added to the mass, and this process is repeated three times. The mixed mass of excrement and coal-ash is then left undisturbed for a period of 14 days, when it is turned over. After another seven days it is again turned over. Then it is left undisturbed a week, when the process of manufacture is complete, and the mass has become pulverulent and inodorous. The proportion of excrement to fine ash in the finished manure is 80 parts of the former to 35 parts of the latter. The sulphuric acid added is in the proportion of 25 lbs. to 1 ton of the excrement.

After the excrement pails have been emptied, they are arranged upon a stand and effectually cleansed by water delivered under 40 lbs. pressure from a hose; and before being again sent out of the yard there is placed in each tub a quantity of "disinfectant" (a half-pint in the cooler months and one pint in the warmer) made at the works from the following formula :—

Chloride of lime - - - -	10 parts.
Crude alum - - - -	10 „
Brown sugar - - - -	1 „
Water - - - -	100, mix.

This antiseptic has been adopted as giving the most satisfactory effects in arresting decomposition, after a trial of sulphate of iron, and other antiseptics. The vans also are sluiced out after each round; once a week they are thoroughly cleansed inside and out; and occasionally the interior is coated with gas-tar.

Of the economical advantages of the Rochdale system actually and as

compared with the midden system, the following tabulated statements, prepared for the Corporation, have been submitted to me. These statements show that while for the period referred to in the first table, the net cost per annum, per 1,000 of population, for the removal and disposal of excrement and dry house refuse on the midden system in the towns named was in one instance (the maximum) 77*l.*, and in another instance (the minimum) 35*l.*, the average for the whole of the towns being 57*l.*, the net cost of the Rochdale system in 1873 was 19*l.* only. I subjoin a detailed account of one week's collection and manufacture on the new system, taken from the explanation already referred to.

Midden System.

Table showing the net Cost of removing and disposing of Night Soil, &c., on the Midden System, in the surrounding Towns whose populations are similar, and whose market for the sale of manure is the same as Rochdale.

—	Cost 1872.	Population.	Cost per 1,000 persons per annum.
	£		£
Rochdale - - - - -	1,596	22,484	71
Oldham - - - - -	6,478	84,000	77
Bolton - - - . -	2,966	84,853	35
Manchester - - -	21,700	360,000	60
Salford (township) - -	4,508	83,280	54
Pendleton (township)- -	1,164	26,574	44
Ashton - - - - -	1,982	32,800	60

Rochdale System.

Table showing the Cost of the Removal of the Night Soil of the Town of Rochdale, and its Manufacture into a Manure by the Rochdale System.

Year ending	No. of closets.	Collected. Excreta.	Collected. Ashes.	Manure. Made.	Manure. Sold.	Houses.	Mills and Workshops.	No. of Persons using the Privies.	Gross Expenditure.	Manure made.	Net Cost.
	Tons.	Tons.	Tons.	Tons.	Tons.				£ s. d.	£ s. d.	£ s. d.
1870, Mar. 31	527	398	611	377	217	1,048	12	5,797	694 17 6	537 19 5	156 18 1
1871 „	1,070	846	1,521	1,059	699	2,944	31	11,770	1,538 7 11	1,380 14 3	157 13 7
1872 „	1,690	1,431	2,405	1,556	1,019	3,174	39	19,283	2,392 13 0	2.167 17 3	224 15 9
1873 „	2,509	1,989	3,413	1,989	412	4,560	69	26,984	3,463 6 11	2,826 16 1	637 10 10
1874 „	3,980*	3,516	5,196	3,497	1,543	7,287	106	†48,500	5,284 3 7	4,449 11 2	834 12 5

* Increase 1,471, of which 165 were for new houses.
† Being two-thirds of the borough.

Statements showing separately the Cost of Collection and Manufacture on the Rochdale System.

Week ending September 24th, 1873.

Number of privies on the new system - - - -	3,354
Number of dwelling-houses to do. - - - -	6,213
Number of factories and workshops to do. - - -	76
Number of population - - - - - - -	36,894

The total weight collected from the before-named places was—

Ashes, - - - - - - - -	96 tons.
Excreta - - - - - - - -	71 „
Or a total of - - - - - -	167 tons.

No. 1. COST OF A WEEKS' COLLECTION.

	£	s.	d.
3 receptacle washers, at 22/0 per week - - -	3	6	0
2 labourers to load and unload carts - - -	2	4	0
16 collectors, including 8 carters, at 22/6 per week -	18	0	0
Keep of 8 horses, including farriery and saddlery, but not rent - - -	6	16	0
Horse keeper - -	1	5	0
3 labourers or wharfmen for storing and loading for sale, each labourer having to store 9 tons odd each per day in addition to loading - - -	3	6	0
Book-keeper and wharfinger	1	10	0
Office boy - - -	0	15	0
Town inspector and manager	2	0	0
Carried forward -	39	2	0

	£	s.	d.	£	s.	d.
Brought forward				39	2	0
The capital and depreciation is as follows:—						
Receptacles value 1,200*l.*, depn. per annum -	240	0	0			
Ash tubs value 125*l.*, depn. per annum -	25	0	0			
Horses and gear value 700*l.*, depn. per annum	100	0	0			
Vans and carts value 450*l.*, depn. per annum -	64	0	0			
Capital in plant 2,475*l.*, interest	123	15	0			
Rent of wharf and stables, rates, taxes, &c.	150	0	0			
	£702	15	0			
702*l.* 15*s.* per annum is per week - - -				13	10	3
Total weekly cost of collection equal to 6/3½ per ton - -				£52	12	3

No. 2. MANUFACTURE: A WEEKLY BALANCE SHEET.

Dr.	£	s.	d.	£	s.	d.
Wages:—						
3 cinder sifters @ 22*s.* 6*d.* -	3	7	6			
1 manager and engine tender -	1	10	0			
2 labourers -	2	4	0			
1 boy - -	0	7	6			
				7	9	0
Materials:—						
Chemicals -	8	0	0			
Bags - -	1	0	0			
Implements and machinery -	1	0	0			
				10	0	0
Depreciation:—						
2 per cent. per annum on 4,730*l.* for plant -	1	17	0			
				1	17	0
Capital:						
5 per cent. per annum on 4,730*l.* -				4	10	0
				£23	16	0

Cr.	£	s.	d.	£	s.	d.
By 71 tons of manure @ 1*l.* per ton - - -				71	0	0
By 28 tons of cinders for sale @ 1*s.* 6*d.* per ton -				2	2	0
By rags, iron, glass, &c.,—say - - -				0	5	0
				73	7	0
Deduct—						
By cost of manufacture, as on Dr. side -	23	16	0			
By commission to agents on sale of manure -	7	2	0			
				30	18	0
By net profit on manufacture - - -				£42	9	0
The cost of collection this week was - - -				52	12	3
Deduct profit on manufacture - - -				42	9	0
Making the total cost to the town - - -				£10	3	3

for the removal of excreta and house refuse of a population of 36,894, being at the rate of 14*l.* 6*s.* 8*d.* per 1,000, per annum.

The manure made is here put down at its selling price, although its value as now made is much greater than it was formerly, as four tons of night soil are now used to $1\frac{3}{4}$ tons of ash.

The 167 tons of night soil and refuse thus dealt with by the manufactory was disposed of as follows :—

	56	tons of cinders.
	8	„ refuse, rags, glass, paper, &c.
	32	„ water evaporated.
	71	„ manure made.
Total	167	

Another statement by way of comparison between the economic working of the midden and pail systems has also been made to me. Taking the whole borough within its enlarged limits, 44,000 of the population are under the pail system and 22,000 under the midden system. The staff and plant required for the scavenging of 4,000 closets under the pail system consist of 11 carters, 11 other men, "guards," 9 night-soil vans, 10 dust carts, and 11 horses. The staff and plant required for the scavenging of 2,000 closets under the midden system, consist of nine carters, nine emptiers, one foreman, 10 carts, and 9 horses.

When Dr. Buchanan and I studied the working of the Rochdale system, as it was seen in operation in 1869, we formed a high opinion of its advantages as a means of controlling and abating excrement nuisance, particularly as compared with the system for which it was being substituted. In the recent inspection I have again submitted the working of the system, so far as it relates to the question of nuisance, to a detailed examination, particularly in view of certain objections which have been urged against it. These objections referred to asserted offensiveness in the changing of the excrement pails and their being carted through the streets, and to averred danger arising from the collection of unmixed excrement in pails. The construction of the closets, as I have already had to observe, at once removes the evils of the middenstead. The absence of marked excremental odour of separate closets used by single families, in the greater number of the instances examined, after seven days use, was remarkable. In one instance only, that of a block of closets opening beneath a common roof and into a common passage, was the odour striking; but even in this case the odour was only perceptible within the building, and was quite inconsiderable compared with the stink of a neighbouring middenstead. The removal of the excrement pails from beneath the closet seat, the affixing of the lids and carriage to and placing within the night-soil van, were done with great celerity and without a trace of nuisance; and I satisfied myself that in this process, and in the subsequent cartage of the tubs, nuisance could only arise from gross carelessness of the scavengers. The Corporation, in addition to exercising a strict supervision over the process, are desirous to diminish even the semblance of nuisance from the removal of the pails. An experiment is now being tried in one district of the town, containing 993 pail-closets, of collecting the excrement pails apart from the collection of the contents of the ash tubs. By increasing the number of vans in this district, and employing the whole of the men, in the first place, upon the removal of the excrement pails, it is hoped to complete this part of the work before 11 a.m., and perhaps even earlier; the collection of the dry house refuse being left to the after part of the

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day. Should this experiment succeed, the same arrangement will be adopted generally throughout the town. I made particular inquiries of householders as to offensiveness arising from the pail system; but in every instance decisive testimony was given as to its inoffensiveness as compared with the midden system, and an equally decisive opinion expressed against a return to the latter system, whether as regards mode of depositing the excrement or of its removal. In order to leave nothing to the imagination, I sought to obtain permission, after inspecting the work of removing the pails and their cartage in the night-soil vans, to have the contents of a middenstead removed before nightfall. But I was foiled in carrying out this perhaps most needless experiment in stink by the officials of the night-soil department objecting to undertake the task during the daytime, for the very significant reason that it would provoke disturbance in the town. Complaints to the Corporation of offence from pail-closets rarely arise; complaints as to offence from midden closets are the rule, for a midden closet is not cleansed except on request of its owner or of the inspector of nuisances—until, in short, it has become a nuisance in the ordinary sense of the word.

The objection urged against the pail-closet as dangerous to health rested upon the assumption that the collection of the unmixed excrement and its cartage through the town would disseminate enteric fever, and other diseases connected with excremental nuisance. No facts are stated in support of the assumption, and it is sufficient to say that the opportunities of such dissemination from the pail-closet as managed at Rochdale are wholly insignificant as compared with the midden-closet for which it is being substituted. It has been overlooked, moreover, by the objectors that the pail-closet gives particular advantages for effectively limiting the prevalence of the diseases referred to. This is one of the reasons which have influenced the Corporation in adopting it.

It is no part of my business to express an opinion upon the ultimate disposal of the excrement and dry house refuse, but I may observe that every care is taken to avoid nuisance in the manufacture of the manure.

Manchester.

MANCHESTER (1871; population, 351,189; inhabited houses, 67,204). —When Dr. Buchanan and I visited Manchester in 1869 there were 10,000 waterclosets and 38,000 middensteads in the city; a middenstead being in many instances used in common by several families. Waterclosets were discouraged except in higher class houses; and changes now being made by the corporation in the construction and regulation of privies other than waterclosets will tend still further to their discouragement. In 1869 the corporation fully recognising the evils arising from the common privy with open middenstead, had instituted itself and permitted others to institute several experimental methods for obviating the offensiveness and unwholesomeness of this form of excrement disposal. These methods were designed to secure in various ways dryness of the contents of the middenstead; diminution of their offensiveness by covering the deposited excrement with ashes and house refuse, and by restricting the amount of accumulation; dispersion of any noxious gases formed during decomposition of the contents at some safe point; and prevention of leakage or soakage from the middenstead. Roofing and drainage of the middenstead, and occasionally a mechanical device for diverting into the drains urine passed at stool, constituted the principal arrangements for obtaining

dryness. Sifted ashes, or a screen so arranged that the fine ash fell upon an inclined plane and was directed beneath the privy seat, or casting the ashes and house refuse in bulk beneath the privy seat, hinged so as to be raised for the purpose, or through an aperture at the level of the privy floor were the means adopted for covering the freshly-deposited excrement, the ashes contributing also by reason of their absorbency to dryness of the middenstead contents. The removal and dispersion of noxious gases formed in the roofed middenstead were sought by a ventilating shaft. Finally the middenstead was restricted in size, and leakage and soakage were provided against by certain peculiarities of construction, or by the substitution of a wood or metal receptacle for the fixed middenstead.

The Corporation at this time required that the several objects aimed at by the arrangements mentioned above should be provided for in all new middenstead privies or middenstead privies which had to be reconstructed, specifying the main structural requirements. These included, with regard to the middenstead, roofing with slates or flags well pointed, and flooring with Rochdale flags of not less than 3 inches in thickness, bedded in mortar, and laid with proper inclination to a drain outlet; and, with regard to the privy, a construction such as to ensure the ashes being deposited upon the excrement, the seat to this end being hinged and having a hinged "riser." The depth of the middenstead was limited to 5 feet from the sill of the emptying hole (2 feet below the level of the ground); and the door of the emptying hole was to be provided with a lock and key of approved pattern.

Notwithstanding the improvement gained in the construction of the common middenstead privy by these regulations, the new middensteads, as Dr. Buchanan and I observed in our departmental report on the subject, were large enough to hold three or four months' accumulation of excrement and refuse; the scavenging arrangements of the Corporation only contemplated the removal of this accumulation when the pit was ready to overflow; and the drainage was fatal to any possible defence of the midden system at all.

Further experience has convinced the Corporation that the accumulation of filth contemplated by the arrangements approved in 1869, although much less than previous accumulation, was inconsistent with wholesomeness of the atmosphere about dwellings; and that the infrequent scavenging which these arrangements involved was not sufficient to meet the sanitary necessities of the city. An examination, moreover, of the drains and smaller sewers in various parts of the city, made under the direction of the medical officer of health, Mr. John Leigh, disclosed a state of things, from the accumulation in them of solid refuse from middensteads, which is best described in Mr. Leigh's own words. He writes in a report, prepared in February 1874, (p. 21) as follows:—

"Some time ago I caused to be sunk in every township of the city a series of shafts down to the drains and sewers situated respectively in courts, passages, narrow secondary streets, and in the broader primary ones. The greatest accumulations I found in the drains at the backs of houses, in courts, passages, and in narrow streets. Some of the drains in these were quite full of solid matter, others had a few inches of space above the deposit. The sewers in the large streets were as a rule comparatively free, though occasionally a large amount of deposit was found. In all openings made into the drains the extent of deposit was generally the greatest at the highest point, gradually tapering off towards the outfall. Upon examination the deposit was found to consist of

small coal, ashes, bits of broken pot and fœcal matter, cemented by the latter into a strong mortar, which after being allowed to stand for a short time gave off very offensive gases, which bubbled up through the deposit. The matter had in fact all been derived from the ashpits and privies. The two figures

Fig. 6.

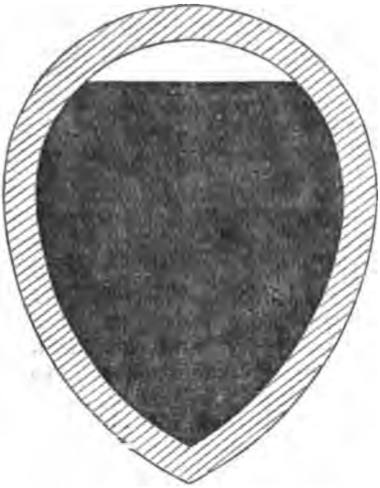
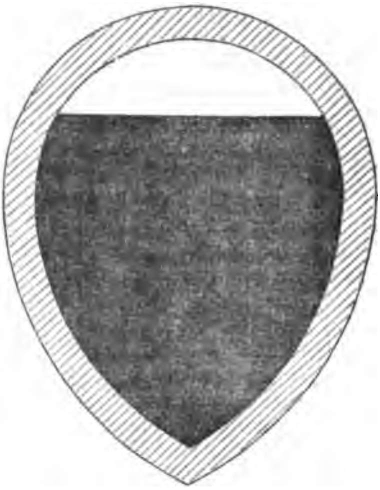
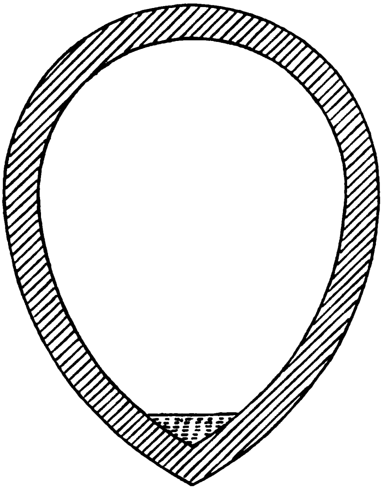


Fig. 7.



(Figs. 6 and 7) represent the sections of a drain in Joddrell Street. It will be seen that the drain is nearly full. The contents were as black as the ink in the diagram, and were excessively offensive. The lowest figure (Fig. 8)

Fig. 8.



represents the section of a drain in a passage behind Collyhurst Road, which had been laid down about eighteen months, and which was not in connexion with any ashpit or privy drain, but drained the adjoining houses. The deposit was about three-fourths of an inch of gray silt or sand. Several drains similarly situated in Chorlton-upon-Medlock were likewise opened with a like result."

In view of the evils left untouched by previous experiments, the Corporation next proceeded to establish a frequent systematic removal

of excremental and other household refuse and to do away with middensteads, substituting for them moveable receptacles. In this way was gradually developed the system of excrement disposal now fully accepted by the Corporation and being put into operation in the city. This system, which involves the reconstruction of all middenstead privies, has already been applied to 6,000 of the 67,000 houses of the city, and is being extended to the rest at the rate of 5,000 houses annually.

The system consists in: 1, the systematic weekly removal (with certain exceptions presently to be named) of the excremental and other household refuse of every house; 2, the substitution of pails for the reception of the excrement and dry refuse, the excrement being deposited in one pail, the dry refuse in another; 3, the covering up of the deposited excrement with fine coal ash; 4, the ventilation in a particular manner of the space beneath and behind the privy seat, in which the excrement and refuse pails are placed; and 5, the utilization of the excrement and other refuse.

The removal of the excrement and other household refuse is carried out by the Corporation itself through the agency of its own staff of men, carts, and horses. As a rule the removal is effected weekly, but in a few cases of small well-ordered families, in which the amount of excrement deposited is insignificant, and its covering up with fine coal-ash can be ensured, a fortnightly removal is authorised; while in lodging-houses and sub-let houses the removal takes place twice or thrice a week according to circumstances. A daily removal will be directed in some localities, if eventually this should be found advisable. The excrement pail, with its contents, is at each removal taken away entirely, a clean pail being deposited beneath the privy seat in its place. The pail, a lid having first been placed upon it to cover the contents, is carried to a covered van constructed after the Rochdale fashion (see *Rochdale* and *Plates* XV. and XVI.), and carted to a depôt. There the contents are emptied out, to be dealt with as described hereafter, and the pail cleansed for re-use. This cleansing was effected by simple brushing at the time of my inspection, the arrangements to be made for washing and disinfecting the pails not having been completed. The contents of the dry-refuse pail are simply emptied into an ordinary scavenger's cart, and the pail replaced. The whole of the process of removal is carried on during the customary working hours of the day.

The use of pails for the reception of the excrement and dry household refuse admits of the old middensteads being filled up, of the drains which formerly ran from these and which were so productive of nuisance being removed, and of the structural arrangements of the privy being wholly kept above the surface of the ground. The excrement pail, made of galvanised iron, is of a capacity of 10 gallons; the dry-refuse pail, made of wood, is commonly 1 foot 10 inches square, and 18 inches high.

The arrangement for covering the deposited excrement with fine coal ash, consists of a cinder-sifter attached to the privy and so designed that the fine ash is directed by a shoot upon the excrement, the cinders falling into a receptacle whence they may be taken for re-burning. The sifter is formed of zinc, with circular perforations half an inch in diameter; this construction having been found by experience less liable to deterioration and to blocking up of the perforations.

Ventilation of the space beneath and behind the privy seat is provided for by a flue which is required to be carried 3 feet above the eaves of the house.

The excrement and dry house refuse are dealt with at the depôt to which they are conveyed in the following manner. The excrement is manufactured into a manure by mixing with it fine coal ash in about equal bulk, and a small proportion of gypsum (1 lb. to 100 lbs. of the

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mingled mass) with the object of fixing ammonia. Subsequently street sweepings and the refuse of slaughter-houses are added. In order to enrich this manure, cottagers are being encouraged to preserve urine, which would otherwise be cast down the drains; the scavengers removing it at the same time as the excrement. The dry house refuse consists chiefly of cinders, broken pots, rags, waste iron, and tin, old boots and shoes, bones, bits of leather, animal and vegetable refuse. The cinders when the arrangements of the Corporation are complete will all ultimately be consumed in the depôt furnaces; the broken pots are ground up with lime and sand for mortar; a ready sale is found for tin and scrap-iron with the copperas manufactures, also for old boots and shoes, bits of leather, woollen rags, and certain animal matters with the prussiate of potash manufacturers, in each case at the rate of 10*s.* per ton. Such refuse as remains unutilized is destroyed by fire.

I add drawings of an elevation and section of the Manchester dry-ash closet (*Plates* XVIII., XIX.); also the detailed specification of the several works required by the Corporation in the reconstruction of privies, together with the illustrative drawings. (*Plates* XX.—XXIV.)

"SPECIFICATION *of the several works required in the reconstruction of* PRIVIES.

Foul earth. "The foul earth under the old ashpits and privies must be entirely taken out, and at once carted away from the works.

Filling in. "The old ashpits must be filled in where required, with suitable dry hard material, small and well rammed in level courses not exceeding 6 inches in thickness.

Ash-pit floors. "The floor of the ashpit is to be flagged with a Rochdale flag, not less than 3 inches in thickness, properly squared and jointed, bedded in mortar, and laid with an inclination of 1 inch towards the door.

Privy floors. "The floor of the privies are to be flagged or tiled, and laid with an inclination of half an inch towards the doors, and raised 9 inches from the level of the yards, or 18 inches from the level of the passage.

Lintels. "The lintels carrying the 4½ inch division walls, between the flues and the privies, must be set flush with the under side of the privy seat.

Cinder sifter from the yard. "A side cinder sifter must be fixed to each privy, and in all cases where practicable must be fixed so that the ashes can be thrown in from the outside of the privy in the yard, and pass down the shoot directly under the privy seat, as per detail drawing No. 2; but in any case where the receptacle is to be emptied from the front, from under a folding riser and seat, or in other special

Cinder sifter inside the privy. cases approved of by the health committee, then the cinder sifter must be fixed at the back of each privy seat, as per detail drawings Nos. 3 and 4.

Refuse frame. "Wherever side cinder sifters are fixed a refuse shoot must be provided, or a door 12 in. by 9 in. (as shown in detail drawing No. 2), and hung to frame 4½ in. by 1½ in. built in, for passing refuse, broken pots, &c.

Privy seat. "The privy seats to be fixed on bearers, 2½ in. by 2 in., let into the flag riser at the front, and secured to the lintel at the back, the depth of the flag from the privy floor to the underside of the seat to be 17 in.

Folding seat. "Where there is no yard space, and a privy is shown underneath a room, a folding riser and seat must be provided (as shown on the detail drawing No. 4), firmly braced together by wrought-iron stays, and hinged with strong wrought-iron bands and gudgeons, the gudgeons being either plated and fixed with screws or driven into the lintels which carry the 4½ in. division wall.

Seat cover. "Each seat is to have a fall cover 1 in. thick, hung with 10 in. bands and gudgeons.

Privy doors and frames. "The doors to the privies must be 1 in. thick ledged doors, hung to frames 4½ in. by 3 in., with strong wrought-iron bands and gudgeons, and left 3 in. short at the top.

Ash-pit frame and doors "The emptying holes of the ashpits shall be 3 ft. 6 in. high by 2 ft. wide inside the door frames, or in special cases (approved by the Health Committee) 19 in. square, and built in with the brickwork, the doors to be cross boarded and finished 1¾ in. thick, and hung to frames 4½ in. by 3 in., with strong bands and gudgeons, and secured with a latch approved by the health committee; the door to overhang and to overlap half its thickness, ¾ in. on three sides on the inside edge of the frame, and to be left ½ in. short at the bottom.

The bottom of the ashpit is to be 3 inches above the level of the adjoining passage, and sleepers 4½ in. by 3 in., for guiding the receptacles, must be fixed as shown on the detail drawings.

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"A galvanised iron receptacle, 15 in. high and 18 in. diameter, together with a wooden receptacle for the cinders, broken pots, &c., 1 ft. 10 in. square by 18 in. high, or in special cases 2 ft. 6 in. long by 18 in. wide and 18 in. high may be procured free of cost, from the Health Committee, at the town's yard, 279, Oldham Road, on production of an order for the same. Receptacles.

"A urine guide must be fixed underneath each seat with screws. Urine guide.

"The ashpits must have ventilating flues constructed of brickwork or of earthenware pipes; the size of the flue to be (if square) 9 in. by 9 in., if of circular earthenware pipes 6 in. diameter, and carried when practicable up the side of the wall to 3 ft. above the eaves of the house, and secured to the walls with strong bands and clips. Ventilating flues.

"The privies and ashpits must be covered with either slated or flagged roofs, well pointed with lime and hair mortar. Roofing.

"The privies must have two coats of limewash. Whitewashing.

"All the woodwork with the exception of the privy seats, must have two coats of good bodied oil paint. Painting.

"The yards must each have a trap and grid, placed in such a position that the waste pipe from the slop stone shall discharge itself on to the grid. Yard grids.

"All flagging and other necessary work to be done to the satisfaction of the Committee. Flagging.

"Cinder sifters, urine guides, &c. may be purchased from the Health Committee, at the Town's Yard, corner of Osborne Street, 279, Oldham Road, Manchester. Cinder sifters, &c.

"Patterns of locks and keys, bands and gudgeons, grids and traps, cinder-sifters, and refuse shoots may be seen at this Office, and no other patterns will be allowed. Locks, hinges, &c.

"The whole of the works to be executed to the entire satisfaction of the officer of health, and to be certified in writing by him. Work to be satisfactory.

"Written notice must be given at this Office three days before the work is commenced, and also when completed. Notices to be given.

"Inquiries to be made at the Health Office, York Chambers, King Street."

The drawings show the most ordinary arrangement of the new closet, but in inspecting reconstructed privies I was struck with the readiness with which the different parts of the closet admitted of being adapted to meet peculiarities of available space.

In order to facilitate the reconstruction of privies the Corporation has established works in which the wood fittings of the closets are manufactured on a great scale, and it supplies these as well as all other fittings to builders. The excrement and dry-refuse pails are furnished by the Corporation free of cost.

In the series of inspections I made with reference to the working of this new system, I had occasion first to observe the contrast as to nuisance between the dry-ash closet and the old midden closet. In several streets where the process of reconstruction had been only partially completed it was possible to compare the old and new privy arrangements in contiguous premises. It was the contrast between open, big, uncleanable cavities, containing a greater or less amount of decomposing fæcal matter, and emitting a horrible, penetrating odour, and between small receptacles emitting hardly any appreciable smell, even with the nose above the privy seat, and admitting of thorough cleansing. Most significant testimony was given to the benefit of the change by some householders. Many houses in Manchester are built in parallel rows, a back passage running between the rows, and each house having a small yard in the rear in which the privy is placed. Since the reconstruction of the privies "*it has been possible to open the back windows of the houses.*" The change, moreover, has affected

beneficially the value of cottage property, and tenants are quite willing to give 3*d.* more rent weekly since the reconstruction of the privies for the gain in decency and comfort. Soakage of excremental matter into the soil, and its passage into and accumulation in drains is, of course, obviated by the reconstruction; and the smaller space occupied by the new closet is not an unimportant matter. The removal of the excrement pails is, with the most ordinary care, free from offensiveness, and if commonly conducted as I saw the operation, it may well be executed during the day-time, and the abomination of night scavenging done away with. The use of the cinder sifters has been adopted by householders with a readiness which proves how accurate the Corporation was in depending upon their co-operation in the working of the scheme. The high price of coal during the last two years has contributed to this good result, from the value of the cinders in economising its use. It is found, also, that a class of the population, commonly believed to be unmanageable in regard to any niceties of arrangement for excrement disposal, have rapidly appreciated the advantages of the new closet, and taken to the use of the cinder-sifter. In other words, it has been found that habits of decency and order in the particular matters referred to have been largely developed with the opportunities for such decency and order. Among the lowest class, occupying sub-let houses, and having privies used by several families in common, it will, however, probably be found necessary to adopt some special supervision, and to remove the excrement and dry-house refuse daily.

Mr. Leigh attaches great value to the deodorising effects of the fine ash. Limiting my remarks upon this subject to what I observed in the actual working of the closet, I would say that when the excrement was fairly covered by fine ash and undisturbed there was no marked odour perceptible from it. But the amount of fine ash scattered above the excrement varied very greatly according to the care given by householders, and more especially according to the times at which the ashes were sifted. Great differences were in consequence observed in the quantity of exposed excrement, and some differences in the fæcal smell. But where least care had been taken, and also where the pail contained simply the uncovered excrement of several days' accumulation, the fæcal odour was inconsiderable.

The success of the new system depends chiefly upon the completeness of the arrangements for the systematic removal of the excrement and other refuse. The scavenging, both of streets and houses in Manchester at the time of my visit was under the control of a Scavenging Committee, while the regulation of privies and ash receptacles was under the charge of the Health Committee. It was a matter of experience that the inability of the Health Committee to exercise direct control over the scavenging of excrement and dry house refuse, interposed a serious difficulty to the efficient exercise of its duties in preventing nuisance from these sources; and the Scavenging Committee had passed a resolution recommending the Corporation to transfer to the Health Committee the charge of the arrangements for the scavenging of "nightsoil" and dry-house refuse. This resolution the Corporation has since approved, and it has now been carried into effect.

Sanguine expectations are entertained that the measures adopted for the utilization of the excrement and other house refuse will ultimately go far to reimburse the Corporation for the costs imposed upon it by the new system. To whatever extent this expectation may be realized, the Corporation by directing the reconstruction of all privies of the old kind upon this new system, manifests confidence in the sufficiency of the

system to meet the sanitary requirements of the city as to abatement of excrement nuisance, and the ultimate disposal of excremental and other dry house refuse.

Halifax.

Halifax (1871, population, 65,510 ; inhabited houses, 13,970).—Few things came under observation during the inquiry conducted by Dr. Buchanan and myself in 1869 more remarkable than the arrangements for excrement disposal in this town. The midden system was that common to the greater number of houses, and was here witnessed in its most repulsive form. The chief object of our visit had been the arrangements existing in the two suburban districts of Akroydon and West Hill Park, built, the former by Colonel Akroyd, M.P., and the latter by Mr. John Crossley, M.P., as models of cottage construction for artisans. The description we then gave still applies, for, with a few exceptions, the cottages in these districts are provided each with midden-closets placed in a small yard in the rear, and constructed to contain several months' accumulation of excrement and dry house-refuse. "At " West Hill Park the ashes are thrown into an opening under the seat, " so that the excrement is well covered, and the pit is roofed in; but at " Akroydon the ashes are thrown in at a separate door, and the middens " are wet and fetid, there being no roof to the pit. At both places the " privies occupy a considerable part of the small back yard, and have the " peculiarity of being sunk two or three steps below the ground level, so " that the pit is of course deeper still. This arrangement makes the " privies less conspicuous objects from the house windows, and when " the pit is roofed flowers are occasionally grown on the top of it. But " this sinking of the privy helps the contamination of the ground by " the excrement, makes the pit more difficult of drainage, and is nowise " to be commended."

In the town newly built privies were observed, constructed according to a regulation which required each house to have its own privy, but in which the privies were placed in blocks above a common midden-stead, the privy seats being hinged so that the ashes could be thrown upon the deposited excrement. We observed of this arrangement at the time, that "it introduced the evil of the public closet without the only justification of such closets, the lessening of the area of filthiness."

The Corporation exacted a charge of from 1*s.* 4*d.* to 2*s.* per cubic yard for removing the contents of middensteads. "Halifax," indeed, as we remarked at the conclusion of our report on that town, "well illustrates " the dependence of constructive arrangements upon the public regula- " tions of the town. A charge for such emptying of a privy (even " though levied according to quantity) amounts in effect to a tax upon " frequent removal of excrement. Pits come to be constructed of the " largest available size, and their contents are retained in the hope of " making a more profitable bargain with some farmer."

Since 1869 the *Goux Patent Absorbent Closet System* has been introduced into the town, and it is estimated that about one-third of the midden-closets have been reconstructed on this system. The total number of closets in the town on the Goux system on the 19th May 1874 was 2,573. Dr. Buchanan and I had seen this system at work in Salford in 1869, and as there managed, as I have stated in my report on that town, we observed no sanitary advantage which was not to be obtained from a simple pail system. A detailed examination of the working of the system in Halifax showed, as a rule, a less degree of offensiveness to the eye than is commonly observed in the simple pail system.

The Goux system is a pail system of which the peculiarity consists in

a certain preparation of the pails and in a particular mode of manufacture of the excrement into manure, and utilization of the dry house-refuse generally. I am here concerned with so much of the system only as relates to the abatement of excrement nuisance in the vicinity of dwellings. The pail used preferably in the Goux system is of wood, of oval form, and measures 24 × 19 inches and 16 inches deep. It is prepared for use by being lined at the sides and bottom three or four inches thick with various refuse matters used as absorbents. These matters may be (to quote from a trade circular) "chaff, chopped or broken straw, damaged or refuse hay, coarse grasses, moor grass, dry street sweepings, dry horse dung and litter, sweepings of markets, hay and straw lofts, refuse wool and hair, wool, shoddy, varic or seaweed, charcoal dust, dry peat, dry ferns, spent dye woods, coal ashes, &c., any, or all of these, or their equivalents, to be mixed in such proportions as may be most convenient, together with a small per-centage of sulphate of iron or sulphate of lime." At Halifax the materials used for lining the tubs are the waste arising from the manufacture of worsted, cotton and flax, and old manure which has become dry and fallen to powder. To these materials a little sulphate of lime is added. The pails are lined with the assistance of a mould as shown in Figs. 9 and 10.

Fig. 9.

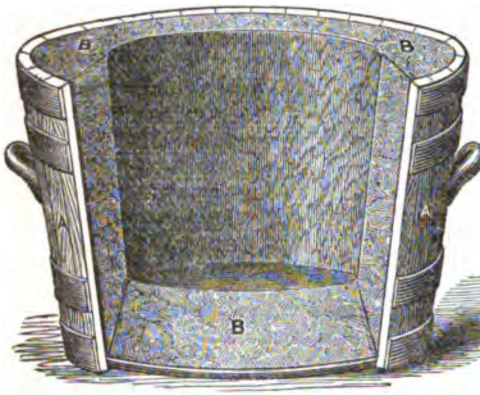

Fig. 10.

Fig. 9 shows in section an oval pail or receptacle, the bottom of which is supplied with absorbent matter at B.

Fig. 10 represents a mould (D) of a diameter less by six inches than that of the receptacle, so that the workman may raise it by the handle (E) and place it in an upright position on the absorbent bed (B), previously laid at the bottom of the receptacle.

The space (BB) which exists round the mould is filled with the same matter as that placed at the bottom.

The lining of the pail is designed to absorb the urine and other liquid which may pass into the pail, and so tend to keep the excrement drier and delay its decomposition; but absorption appeared to me to be very trivial in pails used by women and children. Widely different degrees of sloppiness existed obviously dependent upon differences in the families using the pails; but the extent of sloppiness noticed in Salford, in 1869, was rarely observed in Halifax, greater care being apparently taken in the latter town to avoid the emptying of chamber utensils into the pails. Probably the more regular locking of the doors of the closets which is practised in Halifax contributes not a little to the exclusion of the contents of chamber utensils from the pails, less trouble being experienced in casting them into the yard drain. At

any rate the aspect of the lined pails in use in Halifax generally was less offensive to the eye than of the simple pail, and the casting down of a portion of the lining, as I noticed in several instances, sufficed effectually to hide the offence and to diminish odour from the pail.

The sanitary advantages gained from the introduction of a pail system such as Goux's as compared with the midden system, in Halifax, cannot well be over-rated. The specification for the reconstruction of privies on the Goux system, which is subjoined, necessarily provides for the filling up of middensteads; and the suppression of those receptacles is an initial requisite of sound privy administration in Halifax.

Specification of Works shown on Plates XXV and XXVI.—"The outside walls to be 9-inch and the inside 4½-inch brickwork, set in lime, mortared, neatly pointed at the joints on the inside, and flush-pointed on the outside. Fill up and flag the ash-place [middenstead] with 2-inch flags, so that the same will be level with court or passage. The privy-floor to be 6 inches higher than the ash-place and the adjoining passage. Provide and fix 1¼ inch white wood user and seat with 4½ inch by 3 inch lintel, to back wall. Provide ¾-inch ledged door, which must be hung with bands and crooks to 4½-inch by 1½-inch frame, and secured with strong iron latch and lock with a key for each tenant. The door to the ash-place to be similar but cut in two, and each half to be hung with one pair of bands and crooks. Paint the whole of the woodwork with two coats of good oil-paint, and twice lime wash the inside of both privy and ash-pit. N.B.—The privy and ash-pit must be constructed so as to allow of the effectual removal of the refuse by the system now adopted."

The facility with which a pail-closet, such as the Goux closet, may be adopted to the requirements of old towns, is admirably shown in *Plates* XXVII. and XXVIII., prepared for me by Mr. J. R. Smith, the Sanitary Inspector of the Borough, and showing various adaptations designed by him and carried out in Halifax. I append his description of the plans given in the plates.

The Goux system in Halifax is worked by the company through the agency of its own servants. The company supplies the pails, and it receives from the Corporation for each pail-closet a royalty of 5*s*., and payment at the rate of 7*s*. per annum to the end of the present year (1874), the payment to be increased to 12*s*. if the contract be continued beyond the year. For change of the pails the company has five night-soil vans, constructed on the Rochdale pattern, with the exception of the india-rubber packing for the flaps. Each of these vans is attended by two men. It has also five carts, with eight men attached to them, for the removal of the ashes and dry house refuse. The pails are changed weekly, the exposed part of the lining of the removed pail being broken down and cast over the excrement before the pail is taken from the closet to be placed in the van. Some needless carelessness occurs in lining the pails, in their removal and cleansing, as well as in the cleansing of the night-soil vans, from want of special supervision of the working of the system by officers of the Corporation. I noticed in the course of my inspection pails imperfectly lined, and some not lined at all; pails which had overflowed from neglect to remove them at the proper time; littering of ash-place in the removal of the ashes; some splashing in van and leakage from van into street; and unsatisfactory arrangements for cleansing the vans at the wharf whence the pails are despatched to the manure works. These defects, insignificant as compared with the advantages which those parts of the town derive from the system where it has been introduced, but exciting prejudice against it, entirely arise from the want of such special supervision as the Corporation should exercise over it.

I examined two boat-loads of the filled pails. There was no perceptible odour from them under a hot sun, and I should not have had

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any suspicion of their contents either from sight or smell, had I not previously known what they were. I visited the manure works of the company at Salterhebble. The manure was then being sold, I was informed, at 8*s*. a ton, for re-sale.

Description of Plans, Plates XXVII. and XXVIII.

"No. 1 is a block plan drawn to a scale of 24 feet = 1 inch, limiting the maximum to 12 houses in one block on the back-to-back principle of construction, and arranged for the tub or pail system of collection.

"No. 2. Arrangement selected by the Improvement and Sanitary Committees of the Halifax Corporation for recommendation, to meet the requirements of houses erected on the above-named principle, with reciprocal service, *i.e.*, upon examining plans it will be found that the night-soil tubs are withdrawn from under the closet seats at the back of the closets alternately with the ash tub designed for the accommodation of the corresponding closet on the contrary side.

"No. 3. Alternative arrangement to meet the above requirements and those of separate properties abutting on each other, without reciprocal service.

"No. 4. Alternative arrangement to meet the above requirements with reciprocal service designed for better ventilation and the prevention of offensiveness, the receptacles not being inclosed, but simply roofed over, admitting a more free circulation of fresh air than in arrangement No. 2.

"No. 5. Six closets erected for Mr. Saml. Whitehead in Whitehead's Court, Hanson Lane.

"No. 6. Six closets erected for the late John Abbott, Esquire's executors, in Abbott's Yard, Back Clarence Street.

"No. 7. Four closets, Lilly Street, Claremount.

"No. 8. Eight closets erected for the accommodation of 24 houses belonging to Mr. J. H. Leyland in Queen Street, Cross Field, on a site originally occupied by three privies, and an open ash-pit or midden.

"J. R. Smith,
"Sanitary Inspector."

Nottingham.

Nottingham (1871, population, 86,621 ; inhabited houses, 17,911).—In Nottingham a modification of the pail system is being gradually carried out in the Old Town of peculiar interest. When Dr. Buchanan and I made inquiry as to the arrangements for excrement disposal in the borough in 1869, the use of waterclosets for the poorer classes of the population had, as a result of certain attempts to introduce them made several years before, come to be regarded as impracticable, and the efforts of the Corporation were directed to improving the construction of midden-closets and to the introduction of pail-closets under certain circumstances. A plan of midden-closet had been designed, and had received the approval of the sanitary committee of the Corporation, for securing imperviousness of the middenstead, dryness of its contents, and the proper covering of the deposited excrement with ashes and dry house-refuse, the middenstead being made of a capacity sufficient for four months' accumulation. Several privies had been constructed according to this plan at the time of our visit, but although less offensive than the common middenstead privy, they were open to grave objections. In places where space did not exist for the erection of midden-closets, pail-closets had been introduced. The pails were simple rectangular wooden boxes, receiving excrement only, and they were dealt with, either by tilting the contents into carts or by removal of the pail and the substitution for it of a clean one, daily or at intervals of two or three days, according to circumstances of use. The clean pails had a small quantity of fine coal ash or dry earth placed at the bottom before being put beneath the closet seat.

At my recent visit to Nottingham I found that comparatively few

additions had been made to the number of improved midden-closets existing at the time of the previous visit, and that the chief change made by the Corporation in the arrangements for excrement disposal had been in a certain systematic development of the pail system.

I examined several of the improved midden-closets, including some I had visited in 1869. Although in the better constructed there was some gain of decency in appearance, all were offensive and contained accumulations of filth altogether inconsistent with the wholesomeness of the surrounding premises. In the best the excrement was largely uncovered, and in the worst, notwithstanding a presumed emptying of the middenstead at intervals of three months, the ashes and dry house refuse had become piled up above the level of the opening into the middenstead beneath the seat, converting the space beneath the seat into a trough containing a large amount of decomposing excrement.

The number of pail-closets in use, all within the Old Town, was 2,510, serving for the use of 4,516 houses. This form of closet is now regularly adopted in the Old Town when a new privy has to be erected, or an old privy to be reconstructed. The arrangements of the closet differ from those I have had to describe in other towns, in that separate receptacles are not provided for the excrement and for the ashes and dry house refuse. A single pail answers for both purposes, but householders are instructed to comply with the following notice:—

Dry Closets.

"The substitution of these closets for the ordinary privy and ashpit will, if properly carried out, be a means of preventing offensive smells, which are dangerous to health. In order to accomplish this, the tenants are requested as far as possible to observe the following rules:—

"1st. The fine ashes from fireplaces should be put into the closet tubs, the cinders and unconsumed coal should be first taken out and used for fuel.

"2nd. All other refuse capable of being consumed, such as waste paper, straw, vegetable refuse, pieces of stick, and other like matters should be burnt.

"3rd. Chamber slops must on no account be put into the closet tubs, but should be emptied into the sewer grate.*

"Any complaints of want of attention, or otherwise, should be forwarded to me at the municipal offices.

"Wm. Richards,
"Chief Sanitary Inspector."

In practice I found (and I believe that this is consistent with the general experience of the sanitary officials) that the bulk of the ashes and dry house refuse was thrown into the pail above the excrement, and that, in fact, each pail was a *moveable middenstead*. The structural arrangements of the closet are as simple as in the Hull system, and by substituting a pail for the space beneath the seat, as middenstead, even such slight offensiveness as attaches to the Hull system is avoided, and the facility of dealing with the collected stuff greatly increased. The freedom from offensiveness of the different pails in use examined was notable.

The pail used in Nottingham is made from half of a disused paraffine cask as at Rochdale, and a simple metal lid is placed upon it when it is removed after use. The town is divided into six districts for the change of the pails, and in every instance the used pail is removed to the town-yard for the emptying of its contents and for cleansing, a clean pail being substituted for it at the time of removal. No pail is permitted to remain longer in use than a week, and pails in use by several families

* It has been suggested that the chamber-urine should be thrown into the pail, and the house-slops down the grate.

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are removed at shorter intervals, and in some cases daily. The scavengers arrange their visits upon a rough approximation to the time required for a pail to become half full. The removal is effected by open waggons, a tarpaulin being thrown over the pails; and the process of changing and removing the pails is completed before 10 in the morning in summer, but in the winter it is carried on throughout the day. At the town-yard, which adjoins the canal, the contents of the pails are emptied directly into a barge; the pails are then washed out with a jet of water, and each has placed in it previously to being again put to use, a portion of deodorant powder made from mixing carbolic acid with fresh-slaked lime. The tubs are coated within and without from time to time with fresh coal tar.

Notwithstanding the increase in the number of pail-closets during the last five years, and the attempts to improve the construction of the midden-closet, the common middenstead-privy is still the predominant form of excrement disposal in the borough. The trial is now being made in a few instances of privies constructed so that the ashes are thrown upon the deposited excrement through or beneath the seat, and some restriction is being placed upon the size of middensteads, so that the area of each middenstead shall not exceed five feet square. Abundant illustration of the insufficiency of the first of these arrangements to abate middenstead nuisance, unless combined with smallness of receptacle and frequency of cleansing, will be found in other parts of this report; and the proposed degree of limitation of the size of the middenstead, while, perhaps, diminishing some existing nuisance, will leave the essential evil of the middenstead system—improper accumulation of filth in the vicinity of dwellings—untouched.

Nottingham readily gets rid of its midden-closet and pail-closet refuse. Both are as a rule in regular demand for farms in the vicinity of the borough, and along the line of canal. At the wharf the midden-closet refuse sells at 2*s.* a ton, and the pail-closet refuse at 3*s.*, exclusive of carriage. When deposited in the barges the refuse from the slaughter-houses and markets, and some stable manure are added, also urine collected from the public urinals. A store of street sweepings is kept in the yard to obviate any sloppiness of the contents of the barges. In 1873 the total refuse removed from the town (exclusive of street sweepings) was 32,619 tons, of which 31,926 tons consisted of nightsoil and ashes. The total cost of this removal was 8,269*l.* and the receipts for the sale of manure (including charge for carriage) amounted to 3,956*l.*

Leeds.

LEEDS (1871, population, 259,212; inhabited houses, 55,827).—I had occasion early in 1871 to describe the condition of the borough of Leeds, at the close of 1870, with regard to its arrangements for excrement disposal. At that time there were in the borough 30,335 privies communicating with 13,500 middensteads (or "privy-sumps"), 6,348 waterclosets, of which several were tumbler-closets, 277 pail-closets, and 4,500 dry ashpits. The pail-closets were the remains of a system begun in 1863 with the hope of manufacturing profitable manure from the excrement, but which had not been approved by the Corporation.

I then wrote* of the middenstead system in Leeds as follows :—"The " common privy with middenstead is, in fact, still the ordinary pro- " vision for excrement disposal of the great mass of the population, as

* Report on the sanitary state of Leeds, with particular reference to Diarrhœa and Fever, 1871.

" well of the town as of the borough outside the town. Although long
" recognised as the filthiest and most unwholesome mode of excrement
" disposal, it is not only retained in Leeds, but it is perpetuated by the
" building laws of the Corporation in its most objectionable form. . . .
" The greater numbers of the privies and middensteads in Leeds were
" built at a time when either there was no public provision for their
" being cleansed, and the householders were dependent for this process
" upon the convenience or necessities of farmers, or when such public
" provision as existed was without any systematic regulation or super-
" vision. As a consequence it was necessary that middensteads should
" be constructed of so great a capacity as to contain many months'
" accumulation of filth. These receptacles, dug several feet into the
" ground, are, as a rule, lined and built in with walls of highly porous
" brick, and the bottom is either paved with brick or flags, or, as is not
" uncommonly (perhaps more generally) the case, it is formed by the
" natural soil. Some are gulfs so vast that an individual falling acci-
" dentally into them, if aid be not at hand, may readily lose life."

The scavenging of middensteads within the town of Leeds and the suburbs of Holbeck, Hunslet, and part of New Wortley, was, in 1871, carried out by servants of the Corporation, under its direct control. In the rest of the borough this scavenging was effected by owners and occupiers at their own cost, subject to the supervision of an inspector of nuisances for each township. Here the scavenging was regulated solely by the fulness of the middensteads and the convenience of the owners and tenants; and nuisance in respect to the receptacles was interpreted as overfulness, and the additional abomination apt to arise therefrom.

Of the cleansing of the middensteads within the district scavenged by servants of the Corporation I had to say:—

"The work is not performed systematically street by street, in definite order, throughout the sub-districts. It is regulated—(*a*) by notices received from householders requiring the cleansing of their middensteads; (*b*), by information received from the inspectors of nuisances; and (*c*), by the observation of the inspectors and foremen of scavengers and their men. The inspectors and foremen arrange the day's work of the carts, in accordance with the information received from the different sources mentioned; and if this be not sufficient to occupy the whole staff, the spare carts and men are sent to the *worst-known* places, irrespective of notices. The scavengers work during the night, and, on an average, 120 middensteads and ashpits are cleansed nightly. The number of middensteads and ashpits within the scavenging districts is 11,500; and if these were scavenged systematically, at the rate compassed by the present staff, they would be emptied about four times in the year. This would be the best result that could follow from the present regulations of the staff. But, practically, the result must fall far short of this; for the greater part of the scavenging is made conditional upon the convenience of householders, and the amount of provision they possess for the storage of refuse. The existing arrangements, indeed, are sufficient to prevent larger collections of refuse than the receptacles provided for it will contain; but they entirely fail to effect so great a reduction of the excremental filth and other refuse, commonly stored in the vicinity of dwelling-houses, as is needed to affect in any sensible degree their noxious influence upon the health of the inhabitants."

Subsequent to the publication of this report the Corporation again instituted an experimental trial of a pail system of excrement

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removal within a limited district; and since May 1 of the present year (1874) it has caused certain important modifications to be made in the cleansing of middensteads within the area scavenged by its own servants. In other respects the state of Leeds as to its middenstead-privies remains as I described it in 1871, and, except in the limited district referred to, no change has been made in the construction of middensteads.

The *pail system* has been introduced into a district (the East Ward), which contained 1,506 privies and 699 middensteads for the use of a population of 15,000. From the time of introduction to February last, 690 of the middensteads had been filled up, and 1,484 of the privies converted into pail-closets. I have had an opportunity of inspecting parts of this district twice during the course of the alterations. The middenstead privies in this district were among the very worst and most offensive in the borough, and the change effected by their removal and the substitution for them of pail closets is remarkable. The absence from the East Ward of the penetrating midden stink which is so characteristic of Leeds, even in well-to-do parts, is especially noteworthy. The pail system, as first adopted, consisted in the removal of the pails from the closets weekly, and the substitution of clean pails for them. Each pail before being used had been cleansed in the Corporation yard, and a quantity of carbolate of lime placed in it. When removed from the closet a lid was placed over it, and it was carried away in a closed van. As managed complaints quickly arose of sloppiness in the closets, and scattering of contents in the passage of the pails to the vans and through the streets, and much nuisance therefrom. Eventually this arrangement was given up and under the advice of Dr. Goldie, the present medical officer of health, another mode of working the pail system has been adopted.

The causes which, so far as I can gather, appear to have led to this failure of the pail system, as carried into operation at the outset, have been as follows:—first, there was a want of due proportion between the number of pails and the number of families using them, or between the frequency of removal of the pails and the rate at which they filled. The pails adopted were of the capacity used in Rochdale for a single family during one week. In Leeds a pail would frequently serve for the use of several families, and, as a consequence, its contents not rarely overflowed or were liable to be spilled in part during removal. To avoid this evil the pail closets should have been increased in number, or the removal of the pails should have taken place more frequently.

The pail system, as now worked in the East Ward, Leeds, comprises a *daily* emptying of the pails, without changing them, and the use of fine coal-ash to cover the deposited excrement. The use of the fine coal-ash is simply an instruction to householders, and is at present carried out very irregularly. Many houses in the East Ward have ash-pits before the fire-range, into which the fine ash is raked and the cinders separated for re-burning. These ash-pits are only emptied at intervals, usually of a week, and then only in these cases is the fine ash cast into the excrement pails. In an examination of many pails which I made, it was the exception to find ashes above the excrement. The contents of the pails when removed are merely tilted into the nightsoil cart, and the pail is then scraped, sprinkled with carbolate of lime, and replaced. The stink from this process is much less than the description would imply, and incomparably less than the stench from emptying a common middenstead.

The nightsoil scavenging is conducted between the hours of 11 p.m. and 6 a.m., and I made an inspection both of the mode of

emptying the excrement pails and of the ordinary mode of emptying middensteads. Anything more offensive than the process of emptying an ordinary middenstead, particularly when it is sloppy and shut in beneath houses, I cannot conceive. The process is necessarily limited to the night hours; but that the necessity for it should exist in a borough like that of Leeds, I can only explain on the supposition of the absolute ignorance of its nature on the part of those who are responsible for its continuance.

The present mode of working a pail system in Leeds, had been too short a time in operation at the period of my inspection to admit of a definite conclusion being formed as to its particular merits, except with regard to the *daily* cleansing. The enormous advantage gained by this frequent removal of filth, as compared with the old midden-system, is incontestable. Under this system the ashes and dry-house refuse are collected by a separate set of men and carts during the day.

At the suggestion of the superintendent of the sanitary department, Mr. Newhouse, since the 1st May last arrangements have been made for systematically cleansing middensteads and ash-pits by street-row. With some increase of the scavenging staff, this, it is believed, may be effected throughout the district scavenged by the corporation every six weeks.

The four years' work of the Corporation in regard to excrement disposal since my inspection in 1870, may be summed up as follows:—*One sixteenth* (16,000) of the population of the borough or thereabouts, has a pail-system with its great advantages. Not more than six weeks' filth will probably now be permitted to accumulate among *twelve-sixteenths* (192,000), the manner of accumulation remaining unchanged. The state of the remaining *three-sixteenths* (48,000) as to its filth receptacles and the storage therein is unaltered.

Forty-three tumbler-closets are now in use in Leeds. No addition has been made to this number during the last three years. This form of closet is, in fact, now discountenanced, as wasteful of water and difficult to keep in order. In 1870 I found that the regulation of the water supplied to these closets, the control of which is under the Water-works Committee, was not conducted on any definite principle, and that the supply was in several instances quite insufficient for the proper working of the closets. This cause of defective action of tumbler-closets still continues. Further experience has shown, moreover, that the pivot of the tumbler is apt to get out of order, and experiments with pivots formed of various materials have not succeeded in remedying this defect. Finally, much difficulty has arisen from ashes and other rubbish thrown into the trough of the closet.

I subjoin a drawing of a tumbler-closet. (Plate XXIX.)

Cockermouth.

COCKERMOUTH.—In the district of the Cockermouth union rural sanitary authority, I had the opportunity of witnessing the beginning of an interesting and important experiment in excrement disposal which is being carried out by the authority. On the advice of their medical officer of health, Mr. John Makinson Fox, it is seeking to familiarise the rural population with the use of a pail closet, independently of any arrangements for cleansing and dealing with the contents of the pails by the sanitary authority. Part of the scheme is to secure the covering of freshly-deposited excrement with fine coal-ashes, with a view of obviating nuisance from it and of better fitting it for subsequent use as

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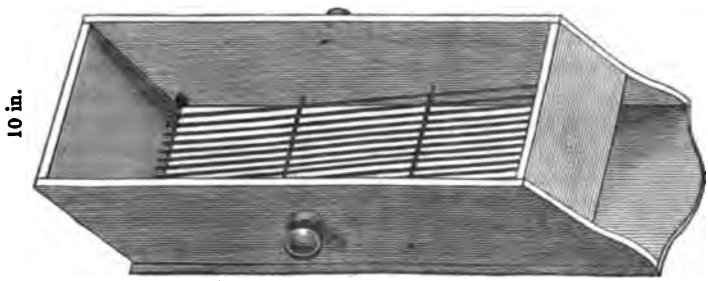
manure. To these ends Mr. Fox has invented a cheap and handy cinder-sifter (Fig. 11), which may be used above the aperture of the

Fig. 11.



closet seat. This sifter, to meet local habit, is also designed for a "trug," the Cumberland term for a dust-box, an article of furniture found in every house.

In furtherance of this experiment and otherwise to provide for improved privies and the abatement of privy nuisance, the sanitary authority (having previously been invested with certain urban powers) has included the following regulations in its byelaws, made under 21 & 22 Vict. c. 98. s. 34, and sanctioned by the Local Government Board on the 9th July in the present year:—

"1. The person constructing any privy and ash-pit in connexion with any new buildings shall construct such privy and ash-pit at a distance of not less than ten feet from any part of any house.

"2. The person constructing any ash-pit or midden privy shall cause the floor and sides of such ash-pit or privy to be cemented or constructed of non-porous materials so as to prevent infiltration into the soil.

"3. The person erecting any privy, may, in lieu of any ash-pit and midden privy constructed as above, provide pails acccording to the following arrangements:—

Every such privy must be constructed with hinges at the back of the seat, that the seat may be raised for the use of the cinder sifter and removal of the pail.

Every house must be provided with a dust box and cinder sifter for the daily covering of the nightsoil with dry ashes from the fire or with dry earth.

"4. The person constructing any privy or ash-pit shall cause it to be placed in a convenient situation, to be constructed with proper materials and of such a size as shall provide adequate accommodation for the premises.

"5. He shall cause the same to be provided with an opening as near to the top as practicable, communicating directly with the external air, or to be otherwise furnished with sufficient means of ventilation.

"6. He shall cause such ash-pit to be roofed in, and to be provided with a side door one yard square."

The sanitary authority has also issued the following special notice with respect to the use of the dust-box and cinder-sifter:—

"COCKERMOUTH UNION RURAL SANITARY AUTHORITY.

"*Dust-box and cinder-sifter for disinfection of nightsoil.*

"Every privy must now be kept, according to the statute so as not to be a nuisance and injurious to health.

"A privy is a nuisance where the nightsoil is allowed to accumulate, or where it is not covered, disinfected, or removed, every day.

"A pail for the reception of the nightsoil is better than the old pit privy.

"The dust-box and cinder-sifter is intended to accomplish the purpose of disinfection with the least possible trouble and expense.

"This box combines the purposes both of a dust-box and cinder-sifter.

"It is to be used every day.

"Each day the ashes and cinders are to be placed in the box on the wire floor.

"The box is then to be taken to the privy, and shaken over the pail.

"The projecting end of the floor is to be placed within the sides of the pail, and after shaking the box, the ashes only will fall upon the contents of the pail.

"The cinders remaining upon the iron floor, may be taken back to the fire or removed to the coal-place, or placed in a separate receptacle for cinders.

"*If the cinders and other house refuse are placed in the pail, they will deprive the whole of its contents of any value.*

"The pail when full, will either be removed by the township, and an empty one left in its place; or the contents may be used in the garden as manure.

"In every case, where there is a difficulty of removal, notice should be given to the inspector.

"It is important that the ashes should be thus used every day. The habit then becomes easy.

"*By this means an infectious and offensive smell will be destroyed, sickness prevented, coal will be economised, and a valuable manure w accumulate for the ultimate benefit of ratepayers.*

"John Makinson Fox.
"Medical Officer of Health to the Authority.

"John Musgrave,
"Clerk to the Authority."

In addition to the foregoing instructions, the inspectors of nuisances are directed to report as nuisances privies in which no attempt is made to keep the excrement covered with ashes or dry earth.

Previous to the constitution of the sanitary authority, pail closets had been introduced into various parts of its district by private enterprise, and the efforts to bring them into more general use have thus been facilitated. The total number of pail closets in the district at the time of my inspection was 360, and of these 163 had been constructed at the suggestion of the sanitary authority.

In the several instances I examined in which pail closets had been substituted for the old middenstead privy, the cottagers had not failed to appreciate the greater orderliness and slight offensiveness of the former, as compared with the latter. They recognised the advantages of getting rid of the abiding stink of the old privy, and of having under control any stink which might come from the new privy, if they would take the trouble to sift their ashes over the pail. An incidental inducement to take this trouble was confessed by some, it may be noted, in the high price of coal, which made the recovery of the cinders from the ashes a matter of some consideration. Where cottagers have gardens, little difficulty appears to be experienced in managing pail closets, as it is possible to store the contents of the pails, harmlessly, it is believed, until they can be used as manure, for which purpose they are held in high esteem. In the comparatively few instances where cottages have not gardens, if pail-closets be adopted, it will be necessary to make arrangements for the removal of their contents with neighbouring farmers or possessors of gardens. Each case of construction or reconstruction of a privy on the pail system is, however, being dealt with on its own merits, the object being kept in view, in carrying out the change, to endeavour to effect it mainly through the agency of the

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people themselves. Proprietors of cottages who have adopted pail closets in connexion with them, have in some instances undertaken the removal of their contents. One instance was mentioned to me of 50 cottages having pail closets, attached to a manufactory, of which the proprietor removed the contents of the pails at intervals to a farm he possessed.

If, as seems not improbable, the success of the experiment undertaken by the Cockermouth union rural sanitary authority should in certain cases, be interfered with by obstacles in the disposal of the contents of the pails the sanitary authority proposes to overcome these obstacles by some supplementary action.

Birmingham.

BIRMINGHAM (1871, population 343,787; inhabited houses, 68,532).—When Dr. Buchanan and I visited Birmingham in 1869, the Corporation had no detailed information of the arrangements for excrement disposal in the borough. Except in better-class houses, midden-privies were in common use, but neither the number nor the structural disposition of the latter was known, and their construction was not subjected to any systematic rule. No byelaws existed regulating the erection of privies or ashpits in new houses, and although plans of new buildings and their appurtenances had to be approved by the borough surveyor, he interfered with the privy arrangement only so far as to require the provision of a drain in the privy pit. For the rest, a builder might as a rule build privies on any plan that suited him uncontrolled by the authorities. There appeared to us, therefore, as we observed in our report of this visit, "No prospect of rapid improvement "on the filthy state of things that exists throughout the poorer parts of "the town."

In 1871, the Corporation appointed a Committee of Inquiry on the best mode of disposing of the sewage of the borough. This committee, presided over by Mr. Alderman Avery, devoted three months to the inquiry, and prepared a detailed report of remarkable interest, which has been published as an independent work.* In the summary account of the results of the inquiry which precedes the report, the Committee state that:—

"The extent of the midden system is now for the first time ascertained. There are in Birmingham 3,884 premises containing 7,065 waterclosets, accommodating about 20,000 persons; and 70,000 houses connected with 19,551 privies and middens, accommodating about 325,000 persons. Of these middens or ashpits, nearly 14,000 are drained into the sewers. The middens cover an area of 16,170 square yards, or about 13½ acres; and practically all of them, containing fæcal water, and solid and liquid refuses are open to the air. Some of them are situated beneath houses or workshops, and large numbers are built against the walls of houses, which are thus permeated with the filthy liquid making through the walls. The consequence is that the sewers are constantly fouled by the drainage from the middens, and that the surface wells gradually become the receptacles of sewage matter, with which the earth surrounding the middens is absolutely saturated." (p. xi.)

The Committee recommended in regard to the midden-stead system, and as part of a plan of excluding almost all excremental matters and trade refuse from the sewers:—

* Borough of Birmingham.—Report of the Sewage Inquiry Committee, 1871. Simpkin, Marshall, & Co.

(*a*.) "The gradual abolition of middens, and substitution of a new "privy system, based upon the principle of exclusion from "the sewers, and weekly collection of all excrementitious "matters solid and liquid." (*b*) "An experimental trial of "the Rochdale and Manchester systems on a sufficiently "large scale, and under the strictest supervision, and "ultimately an extension to the whole town of that system "which shall be found to be the most efficient." (*c*) "The "imposition of a rate on occupiers in respect to water-"closets connected with the sewers on a scale to be "sanctioned by the Council."

The "Manchester system" referred to above is not the system discribed in this report, and now adopted in Manchester, but the system of improved dry privies described in the report of Dr. Buchanan and myself in 1869, and which has since been given up for the pail-system now in process of being introduced generally throughout that city.

In May 1873 an experimental trial of a pail-system, founded upon the Rochdale system, was begun in Birmingham, and at the time of my recent visit 2,700 pail-closets had been constructed in the borough. No compulsory power is exercised by the Corporation in the introduction of these closets, but byelaws are in preparation for their regulation. The Corporation has directed their introduction in new houses where no objection is offered by the owner, and has encouraged their substitution for midden-privies when these have required reconstruction. But it is optional with the owner whether he adopts the pail-closet, the midden-closet, the ordinary watercloset, or a form of trough-closet which has been erected in a few instances. So rapidly, however, is the pail-closet gaining favour with property holders that the present limited means which the Corporation possesses of carrying out the experiment is taxed to the uttermost. This has arisen mainly from want of yard space in which to deal with the collected matters, and pending this difficulty being overcome it has been found necessary to discourage the alteration of midden-closets into pail-closets.

The pails are changed weekly, the clean pail having a portion of antiseptic in it prepared after the Rochdale plan. The arrangements of the Corporation, indeed, generally as to the collection of the excrement pails and dry house refuse, and subsequent manufacture of the excrement into manure and utilization of the refuse follow the Rochdale system as closely as their provisional nature admits. The manure made from the mixed excrement and fine coal-ash sells at *5l.* per boat-load of from 24 to 25 tons, and has even commanded a price of *7s.* a ton. Of the sanitary advantages of the system, as marked by its freedom from nuisance in comparison with the middenstead system, there can be no question; and it is beginning to be perceived that the net cost of the working of the pail-closet may be much less than that of the midden-closet, as has been shown at Rochdale. A prospective advantage of the extension of pail-closets in the borough, mentioned to me, was the probable utilization in the manufacture of manure, of a vast and accumulating deposit ("tip") of middenstead refuse which exists 10 miles from the town. The excrement pail used in Birmingham differs, especially in the arrangement of the lid, from the pail commonly used in Rochdale. It is of galvanized iron, and is of the dimensions and form shown in *Plate* XXX.

During the inspection I made of many of the pail-closets erected in Birmingham, I noted the same freedom from offensiveness which I remarked in the inspection of similar closets elsewhere. But in Birmingham, for the first and, indeed the only, time during the recent

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inquiry, a complaint was made to me of greater offensiveness from pail-closets than from midden-closets. This happened in No. 2 Court, Ward Street, in which an excellently constructed block of pail-closets had been erected. There was certainly more odour within the closets than I had before experienced; but I satisfied myself that this arose from insufficiency of through ventilation of the closet. A neighbouring block of pail-closets (No. 4 Court, Ward Street) constructed in the same style, but much more freely ventilated, was free from the odour which existed in No. 2 Court. I shall elsewhere have to refer to defective through ventilation as favouring a certain degree of offensiveness in earth-closets otherwise fairly managed.

In addition to the introduction of pail-closets, an important change is being made in the cleansing of middensteads, and which is to be regarded as the first step to their systematic scavenging irrespective of notice from householders. The borough has been divided for the purpose of night-soil scavenging into six districts and 36 sub-districts, and arrangements are now made that the applications for the cleansing of middensteads from each sub-district received during the day shall be dealt with during the night following.

The applications to the night-soil department for the cleansing of middensteads and ashpits in 1873 amounted to 26,518, of which 5,826 were received from the inspectors of nuisances. Altogether 27,644 were cleansed in the course of that year, and 163,142 loads of stuff removed. The cost of this cleansing was 24,000*l.* less 3,500*l.* received for the sale of part of the removed material. It is estimated that the cost of working the pail system in the borough, including interest on capital account and depreciation, would not exceed the cost of the present night-soil scavenging by more than 2,000*l.*, while the receipts from the sale of manufactured manure and rough ashes would probably realise 18,000*l.* This estimate does not, however, appear to include the cost of the manufacture of the excrement into manure.

I examined one of the trough-closets referred to in a previous paragraph. The closet in question is in No. 8 Court, Hospital Street. Four closets here, used by 12 families, communicate with a common trough which is designed to be flushed by slops and the rainfall falling in the court. The bottom of the trough was covered with a thick layer of excrement and paper, and the sides were lined with excrement. The stink from the closets was most offensive, and a considerable up-draught through the seats appeared to come from the sewer.

Warrington.

WARRINGTON (1874, population 32,144, inhabited houses 6,044).—The Corporation of Warrington has adopted a pail system of excrement disposal, and is now steadily carrying it out in the borough in new houses, where waterclosets are not adopted, and in the reconstruction of old privies. At the time of my visit to Warrington, in October last, 1,157 pail-closets had to that time been constructed and were in use. Generally the Rochdale system is followed in regulating the pail-closets, but with certain noticeable modifications. The excrement pails are of wood, as at Rochdale, but made, as well as the ash-tubs, on the Corporation premises. The arrangement of the lid is, however, different: first, a piece of canvas is placed over the mouth of the tub, and this is held in place by a circular wooden lid. Then the mouth is closed by an outer metal lid with flange. The pails, after being emptied and washed, have the interiors brushed with a brush made for the purpose, and saturated with a disinfectant, of which also a ladleful, measuring a gill in quantity,

Warrington.

is placed at the bottom of each pail before it is again used. This disinfectant is made from the following formula :

Sulphate of iron	- - -	4 lbs.
Sulphate of zinc	- - -	1 lb.
Chlorate of potash	- - -	$2\frac{1}{2}$ lbs.
Hydrochloric acid	- - -	2 lbs.

Water to 40 gallons. Mix.

In the construction of the closets, preference is given to a pent-house, beneath which to place the ash-tub.

Salford.

SALFORD.—The borough of Salford has not yet emerged from the experimental stage as to excrement disposal, in which it was found by Dr. Buchanan and myself, when we visited it in 1869. At that time, here as in Manchester, the Corporation was seeking some way of permanently abating the nuisance arising from the many middenstead privies in the borough, then with certain exceptions presently to be mentioned, numbering 21,642, and serving, together with 1,500 waterclosets, for 25,555 houses; now, with similar exceptions, numbering 26,184, and with no greater quantity of waterclosets, serving for 29,423 houses. The byelaws of the Corporation required that every dwelling house should have at least one watercloset or privy, and that "every privy should be "placed outside the dwelling house, and should have an opening to the "external air, near the top thereof of at least 12 square inches, and the "receptacle for the soil should be separated from the wall of the dwelling "house by a space of at least 3 feet, and should have a drain therefrom, "to, or to some drain communicating with, the sewer in the adjoining "street or court, and should be so constructed as to prevent nuisance." By a resolution of the health committee of the Corporation, the building sub-committee had been instructed to require that all ash-pits (middensteads) to new buildings should be made of a *minimum* size of 3 feet by 4 feet 6 inches; and in respect to old constructions, the Corporation by virtue of powers possessed under the Salford Borough Improvement Act could require alteration to the same type to be made.

While the privies of new houses were generally being constructed according to the byelaws and the resolution of the health committee, two experimental methods of excrement disposal had been put in operation by the Corporation, chiefly in parts of the borough where privy nuisance was greatest, and involving reconstruction of existing privies. One of these methods was an improved form of middenstead-privy, a "dry privy," so called; the other was a pail-privy, managed upon a particular plan, and designated, after the inventor, *Goux's Patent Absorbent Closet System.*

The dry privy consisted of a water-tight receptacle beneath the seat, into which was intended to be thrown, through an aperture, beneath a step ("the tread"), attached to the "riser" of the seat, the ashes and dry-house refuse, so as to cover the excrement. The seat was hinged, so that it could be thrown back, and the floor made movable, to admit of the receptacle being cleansed. A ventilating flue was carried from the upper part of the receptacle several feet above the roof of the privy. About 200 privies of this pattern had been constructed at the time of our visit. We inspected several, and as we then reported, "except where a closet was locked, and its use restricted to a "single family, or at the most two or three families, we found them in "a most unsatisfactory state." In the cases where privies of this kind were used by several families, we found the aperture beneath "the

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tread" more or less choked, the floor littered with filth, the litter extending about the doorway, and the excrement largely uncovered. They were, in fact, almost as offensive as the privies for which they had been substituted, and were not less filthy in their surroundings. The result of this experiment has not been such as to induce the Corporation to approve of the multiplication of these privies. Several of those constructed at the time when Dr. Buchanan and I visited Salford remain. I re-inspected a few, and their state confirmed the opinion formed upon them in 1869.

Of Goux's Patent Absorbent Closet System, as seen in operation in Salford by Dr. Buchanan and myself, we reported as follows:—

"We inspected many pail-closets used by single families, and others used by several families, or by the inmates of a common lodging-house. In every instance where a pail had been in use over two or three days, the capacity of absorption of the liquid dejections, claimed by the patentee for the absorbent material, had been exceeded; and whenever a pail had been four or five days or a week in use it was filled to the extent of two-thirds or more of its cavity with liquid dejections, in which the solid excrement was floating. The contents, in fact, differed nowise in aspect, except in the cases where a portion of the dyewood lining had broken down and fallen into the liquid, from what we should have expected if a simple unprepared pail had been used. It was suggested that a part of the sloppiness of the pails probably depended upon the fact of chamber pots having been emptied into them; but although the regulations for their use permit this to be done, we did not always find on inquiry that even this source of wetness had been in operation."

The subsequent experience of the system has not induced the Corporation to continue it, partly because it did not appear to yield any sanitary advantages over a simple pail system, partly from a distrust of the economic results to be obtained from it in the manufacture of manure. This manufacture, it is proper to add, was carried out as a matter of private enterprise, and not by the Corporation; and the method differed in some details from that proposed by M. Goux. The manufacture did not prove a commercial success, and with its cessation the use of the Goux system also ceased.

I have given a description of this system in my account of Halifax, in which town it has been put in operation somewhat extensively. Here results were observed, during the recent inspection, more favourable to the working of the system than had been witnessed in Salford in 1869, and more in accordance with the statements of the projector.

The privies which had been re-constructed in Salford for the Goux system, about 2,000 in number, are now used as simple pail-closets, the pails being changed weekly, or as often as required. The van used for their removal is constructed after the Rochdale pattern. The contents of the pails are mixed with middenstead and other refuse which can be used for manure, except a portion that is put at the command of a company, The Universal Charcoal and Sewage Company Limited, which, by permission of the Corporation, is carrying on certain experiments in manure manufacture in the municipal scavenging depôt, or "Town yard."

The Salford Corporation, dissatisfied with the results of the experiments as to excrement disposal which it had already instituted, is still carrying out, or permitting to be carried out, other experiments. These experiments, however, do not appear to be undertaken upon a definite plan, or with any clear conception of the principles which should govern

the removal of filth from the midst of a community. They seem rather to be the expression of irregular impulses, and from the mere multiplication of methods, their tendency is more to complicate than to simplify the difficulties besetting the subject. Meanwhile middenstead-privies of the old, offensive type still enormously preponderate, and even are increasing in number. For the middenstead-privies commonly constructed under the byelaws, differ too little in actual harmfulness from the privies of the old type to be dissociated from them.

In addition to the pail-closets and dry-privies already referred to, I observed, during the recent inspection: (1) A so-called modified midden-closet, of which, although it was roofed and built with some care, it is sufficient to say that it was specially constructed to hold from three to six months' excremental and dry-house refuse of the families using it, and thus limit the necessity for cleansing to those periods. This form of midden-closet, in fact, exhibited an actual adoption of the evil which it should be a principal object of the Corporation to remove, namely, the evil of large accumulation of filth in the vicinity of dwelling houses.* (2) The Manchester plan of dry-ash closet, in a few instances. (3) Another form of dry-ash closet (Morrell's). (4) A so-called "self-acting watercloset."

The closet, known as *Morrell's Patent Ash-Screening Closet*, now the property of a particular company (*the Sanitary and Economic Manure Company, Limited*), has been recently adopted, by direction of the sanitary committee of the Pendleton district of the borough, in upwards of 300 houses. This closet was one of the earliest invented of the dry-ash closets, and examples of it were seen by Dr. Buchanan and myself in operation in Manchester in 1869, but not under conditions which would admit of our forming a judgment as to its general applicability to a civil population. The dry-ash closet now adopted in Manchester is formed essentially upon the same principles as Mr. Morrell's closet. His closet differs from the Manchester closet in the mechanism for distributing the fine-ash over the excrement, and in the absence of means of ventilating the space behind and beneath the seat; but the objects it is designed to answer are the same. I give Mr. Morrell's own description of the arrangements of his closet, taken from a paper read by him before the National Health Society.

Description of Morrell's Combined cinder-sifter and ash-closet.

"The system which I advocate," he says, "provides for the perfect separation of the *ashdust* from the *cinders* by means of a screen or sieve of galvanised woven wire placed at the rear or side of the ordinary closet into which house ashes may fall by being simply thrown, as now, through a hole in the wall. Attached to this screen are parts which form a hopper for receiving the ashes. This screen and hopper, forming one, are connected by a simple lever arrangement to the seat of the closet, or by a foot treadle in front of the seat in such a manner that, when the closet is used, an agitating motion is given to the screener by which the cinders are made to fall down the incline, the ash dust dropping through into the hopper below, and thence into a small receiver from

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* The following note attached to the detail drawing of this modified privy, issued by the Corporation, sufficiently describes the structure:—

"The ashpit to be made with the bottom 1 ft. 2 in. below the level of the passage, and with a fall of 6 in. from under the seat. A well-hole under the ashpit, to be built with bend pipe as shown, and properly connected with sewer. The ashpit to be roofed in and well ventilated. The floors of the ashpits to be 3 in. Rochdale flags, laid on concrete. The privy seat to be hinged to turn back, so as to allow ashes to be thrown over the soil. Openings to be made on the yard side 2 ft. by 2 ft., for the ashes to be thrown into the ashpit. A door, 3 ft. 6 in. by 2 ft., to be placed on the passage side for the purpose of emptying the ashpit. The whole to be finished to the entire satisfaction of the medical officer of health" [who, however, it is proper to add, disapproves wholly of the structure].

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which it in meted out in the exact quantity required over the recent dejection, when tbe seat is vacated. Thus the ash dust is by this simple, self-acting contrivance separated from the cinders, and on each use of the closet is made to serve as a sanitary agent by arresting the decomposition of the fæcal refuse, the cinders being thrown simultaneously on to the coal heap, or on to the floor, or into a box for re-consumption at the house fire.

Material which may be added.

"House sweepings, dried earth, or any other dry material may be thrown in with the ashes, as the screener rejects all the portions unsuited for use in the closet.

Receptacle for soil.

"The receptacle for the soil may be a moveable vessel or a fixed water-tight trough. In general practice my impression is that a fixed trough made of a small capacity, corresponding, say with the size of the seat in length and breadth, and of about 1 foot to 2 feet deep, and emptied at one end, will prove the most serviceable and efficient. The application of this arrangement to existing structures is best accomplished by filling up the cess or ash midden to the level of the surface with (in case the small vault is used) the exception of the space it will occupy below the seat.

Space occupied.

"The total space, then, occupied will be an addition to the privy proper, but only by as much as is taken up by the screener, which will usually be found to be much less than that occupied by the old ash-midden. For new erections the total space absolutely necessary need not exceed 6ft. by 2 ft. 6 in., but these dimensions can be extended if larger premises are preferred.

Application for access from interior of house.

"If it is desired to apply the system so that the closet can be entered from the inside of the house, the screening portion of the apparatus can be placed as a projection from the external wall, and be accessible for charging with ashes from the outside. In this case the privacy of the closet proper is preserved, and all the advantage of the internal earth-closet secured, whilst the cinders are thrown for collection outside and the vault emptied, or the soil and removed from the outside."

I inspected several of these closets in operation in Pendleton. They presented all the cardinal advantages in the diminution of privy nuisance which I had occasion to observe in the Manchester dry-ash closet. The stink and the porous middenstead were got rid of; the accumulation of filth was brought within a small compass; and nuisance from the freshly-deposited excrement was obviated by the fine ash cast upon it. The closets had been too little time in use to enable me to form an opinion on the comparative merits of Mr. Morrell's arrangement and the Manchester arrangement for screening the ashes.

The "self-acting watercloset" which has been referred to is a form of closet designed and patented by the borough surveyor, Mr. Alfred M. Fowler. It is now being somewhat largely adopted in the town of Salford. This closet is arranged to be flushed by slop and waste water without the use of town's water. The closet is formed by fixing a trapped pan at such a level that the waste water from the sink, the slops from the house, and the rain water from the roof are carried by a covered drain into the trapped pan. A very similar arrangement exists in some of the Bristol privies, and it appeared to me that the conditions for the successful working of Mr. Fowler's closet would be found to be the same as for the Bristol privy, namely, frequent systematic inspection; the sanitary authority being prepared to cleanse, and undertaking the cleansing of the privies where necessary; and a plentiful and readily accessible supply of water.

I give drawings (Plate XXXI.) showing a section of Morrell's closet as applied in McCleary St. Pendleton (Salford), also a section of the privies for which Morrell's closet has been substituted.

The Universal Charcoal and Sewage Company, Limited, to which reference has been made as carrying out certain operations in the Salford Town Yard, has patented a process for manufacturing charcoal from *street sweepings*. It proposes, while fully utilizing a form of refuse often most difficult to be got rid of at a loss by local authorities, to

provide a charcoal fitted for all sanitary and some other large purposes to which charcoal can be applied, at a cost considerably less than the ordinary charcoals of commerce. The charcoal mixed with nightsoil is said to form a valuable manure, and manure is being manufactured in this way by the Company in the Salford "Town yard." I shall have to refer to the operations of this Company again, when I describe the charcoal process of excrement disposal.

Oldham.

OLDHAM (1871, population, 82,629; inhabited houses, 16,739).—The Corporation of Oldham has adopted a pail system throughout the municipal borough. When Dr. Beard inspected the borough in 1872 the then existing arrangements for excrement-disposal consisted of 1,300 water-closets, 1,800 pail-closets, and 6,200 midden-closets of the old offensive type. Now, less than 50 midden-closets remain in the borough, and for the remainder pail-closets have been substituted. At the time of my visit to Oldham, the Corporation had entered into an agreement with the Carbon Fertilizer Company, Limited, by which the Company on payment by the Corporation of 3*s.* per closet, exclusive of closets attached to mills and workshops (the scavenging of which is conceded to the Company free of charge), undertook the collection of the pails and the disposal of their contents. The Company, I was given to understand, proposes to use charcoal in detail for the different closets, as also in dealing with the collected excrement in bulk for commercial purposes (see section on *Charcoal System*). My visit happened at a time when the arrangements under this agreement had not come into full operation, and before an opinion could be formed of the hygienic value of the system. I refrain, therefore, from describing the working of the pail-closets at Oldham, excepting so far as to state that the Company were collecting the pails, systematically, at weekly intervals.

Gaddesden (Little).

GADDESDEN (LITTLE), Herts.—Here certain cottages, built in couples, on the estate of Earl Brownlow, have had erected for their use improved privies after the following design. A short distance in rear of each couple of cottages, a block of outhouses has been built, constructed of concrete, and containing for each cottage a garden-tool and coal house, a pigsty, and a privy. The privy is fitted, beneath the seat, with a rectangular iron receptacle on wheels. This receptacle can be readily withdrawn through a door at the side of the privy, and one end of it is made moveable on a horizontal axis, the easier to discharge the contents. But this moveable end admits of leakage of fluid, and to obviate the nuisance from this source as well as to facilitate the thorough cleansing of the flagged space beneath the privy seat, the floor of this space is provided with a drain. In one instance where leakage was considerable, this drain did not appear to be acting, and a very noisome puddle had collected beneath the receptacle. When the receptacle is full, it is drawn out, and its contents, covered with vegetable refuse or earth, stored where convenient, or at once used, in the garden plot attached to each cottage.

The conception of this plan of excrement disposal is good, but it fails in certain details. The moveable end of the receptacle is objectionable as leading to nuisance, and the drain beneath the privy seat, while serving the purpose of cleansing the space there, is to be condemned as an outlet for urine and fluid fæces. No sufficient care seemed to be taken to cover the deposited excrement with ashes and dry house refuse, needless stink thus arising; the collected material, moreover, being in

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a state not well fitted for deposit in the garden. The cottages obtain their water supply from waterworks, and there is apparently no danger to this supply even from a careless use of excrement in cultivating the garden.

Paisley.

PAISLEY.—(*Colquhoun's Closets.*)—At Paisley, in certain manufactories, a peculiar kind of closet, invented by a Mr. John Colquhoun, has been for some time in use. This closet aims at dryness of the contents and continuous removal of any effluvium which may arise from them. The receptacle consists of a moveable pan, with aperture at the bottom communicating with a drain. The bottom of the pan is packed with furnace ashes, gravel, or coarse peat through which the urine is presumed to filter into the drain, and thence flow to a tank arranged for its reception. The solid excrement remaining in the receptacle should, by reason of its dryness prove little offensive, and any odour which might arise from it ought to pass away through a flue carried from the space beneath the closet seat and about the receptacle to a convenient chimney, kitchen or furnace, as the case may be. I examined the operation of these closets in the Anchor Thread works (Messrs. Clark & Co.), where several have been in use two years and a half. Personal examination showed sloppy receptacles, indicating obstruction of the filtering material; and the stink from these receptacles proved that the effluvium shafts exercised little or no effect at the time, although the furnace flue to which they were attached must have been in free action. Information given to me by one of the members of the firm, and by the overseer responsible for the supervision of the closets was to the effect, that at the best there was more smell from the closets than was desirable, and that waterclosets would be substituted for them but for a difficulty in disposing of the sewage. The firm were about to adopt experimentally a charcoal closet in one part of the works, and a new part of the manufactory had been fitted with waterclosets.

EXCREMENT DISPOSAL BY WATER-CARRIAGE.

Excrement Disposal as to certain kinds of Water-Closets.

Liverpool.

LIVERPOOL.—Since Dr. Buchanan and I visited Liverpool in 1869, no change has occurred in the measures adopted by the Corporation with respect to excrement disposal which we then described. It is simply necessary for me to reproduce our report of that date, intercalating certain figures where alterations of number have taken place during the past five years; and further to state that the recent inspection has fully confirmed the opinion expressed in 1869 on the efficiency of the trough watercloset.

"This town has particular interest as showing very remarkable recent improvements in the matters with which this inquiry deals. The midden-closet, which was formerly the only sort of privy for the poorer parts of Liverpool, was constructed on the worst possible plan; and in some courts whole rows of houses had their foundations tunnelled by long excrement receptacles. Some progress in lessening the disgusting nuisances from these arrangements was reported to the department by one of us (Dr. Buchanan), in 1864. Besides improved supervision and monthly removal of midden contents, 2,639 privies in particular houses and in some few courts had, in the 11 previous years, been converted

into waterclosets. But it is since 1864, under the greater powers conferred by the Local Sanitary Amendment Act of that year, that chief progress has been made. There are indeed parts of Liverpool reported at the earlier inspection which cannot now be recognised for the close and fœtid places which they then were. Courts of crowded houses have been demolished, and free ventilation between streets and rows of houses has been obtained. Without these improvements much of the very great amendment that is now seen in the arrangements for filth removal would not have been possible.

"In advising measures for improving the excrement removal arrangements hitherto existing in the town, the medical officer of health, Dr. Trench, has consistently kept in view two principles: the one, to deal only with such midden privies as were, for one reason or another, nuisances, or injurious to health; and the other, to remedy such nuisance or injury in a definite way, by the conversion of these privies into waterclosets of a sort approved by the Corporation. He was met at the outset by difficulties arising from the poverty of owners of property, but the Corporation overcame these difficulties by making contributions from the public funds in cases where the conversion of privies was ordered by the health officer.

"In applying his first principle, Dr. Trench had to lay down, as generally as possible, conditions under which an existing midden privy was to be regarded as a nuisance. The following are such conditions, and they constitute so valuable a code for the general guidance of authorities under like circumstances, that we reproduce them from Dr. Trench's notes of evidence given before the Rivers Pollution Commission. It will be seen that Dr. Trench regards position of a midden privy as being much more important than its construction, in determining whether or not it may be allowed to remain. [The construction and position of new privies are otherwise regulated.]

" 'The Act of 1854 provides that, 'when it shall have been certified 'by the medical officer of health that any privy or cesspool was in a 'condition, state, or situation injurious, dangerous, or prejudicial to the 'health of any inhabitants of the borough,' the owner thereof may be required within a reasonable time 'effectually to abate and remedy 'the same to the satisfaction of the Council.' In giving practical effect to the above powers of the law, it became necessary at once and *in limine* to define the nature of the required remedy, and also, as far as possible, the conditions which would justify the certificate of the medical officer. In November 1863, and on subsequent occasions, he laid down certain rules by which he would be directed in the exercise of his certificates. He proposed to certify against,—

" 1stly. Midden-privies inside houses.
" 2ndly. Midden-privies emptied through houses.
" 3rdly. Midden-privies situated beneath rooms.
" 4thly. Tunnel middens of every description.
" 5thly. Combined open middens supplying many tenements and placed near to inhabited rooms.
" 6thly. Midden-privies of private houses clustered together in a *cul-de-sac*.
" 7thly. Midden-privies of private houses in close confined yards or situated beneath windows, or abutting on the walls of houses, or within two feet of the lower windows, or of the door of the house.
" 8thly. Midden-privies of courts.

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"9thly. Midden-privies abutting on or opening directly into streets and thoroughfares, and emptied before the doors and windows of houses.

"10thly. Midden-privies of front houses when emptied through a court.

"11thly. Midden-privies beneath the footpath of the street and emptied through a grid on the footpath.

"12thly. Midden-privies of many houses, when collected together as a kind of amphitheatre, as is seen in particular groups of streets.

"The council, in order to secure uniformity of action, and likewise to prevent future mistakes in the application of remedial measures, directed the town clerk to notify to the several owners against whom proceedings should be taken, 'That it appears to the said council of the 'said borough that the only effectual remedy for such privies and 'cesspools is by converting the same into waterclosets.'"

"Since Dr. Trench has been medical officer, and mostly since 1866, he has ordered and obtained the conversion of 14,393 privies into waterclosets, and there are now (1869) in Liverpool 20,000 privies attached to ashpits, and 31,150 waterclosets, 2,150 of which are tank or trough closets. The extent to which contributory payments have been made by the Corporation has been 40,000*l.*, expended in this manner: 3*l.* 10*s.* has been given for every siphon watercloset ordered to be erected, 5*l.* 10*s.* for a single trough watercloset, and 7*l.* 10*s.* for a double trough watercloset. These closets are constructed on a pattern ordered by the Corporation, and approved as to details by the borough surveyor." [1874. During the four years 1870–73, the number of privies converted into waterclosets was 756, of which 3 were "trough-closets," the rest "siphon-closets." The number of middensteads now in Liverpool is 15,249, the number of privies attached to them about 20,000. The number of "troughs" for trough-closets is 3,304, serving for about 6,000 closets, and the number of waterclosets other than trough-closets 43,395 (1872). The population of Liverpool in 1871 was 493,405, the number of houses, 78,403.]

"The midden privy (which, where retained, has its old pit construction, all the tunnel middens being done away with), and the ordinary siphon watercloset of the single house, require no special description. But there is particular interest in the arrangement and working of the trough closets, which are in use by numerous families in the sort of neighbourhoods where in other towns ordinary waterclosets are commonly a failure and a nuisance. Drawings of these trough closets will be found accompanying this report (*Plates* XXXII. and XXXIII.) and they describe the construction better than can be done in words. It remains to say that the position chosen for these new closets has been carefully determined by the circumstances of each place where they have been erected, and that peculiar facilities for their being well placed have been obtained by the time of their erection concurring with that of other improvements. The closets that are common to several families are cleansed in rotation by the people using them, and a register is kept of the order in which this should be done. Inspectors visiting the closets every two or three days see that this duty is performed, and are themselves held responsible for any shortcoming. By a little patience and firmness the inspector succeeds in obtaining the necessary cleansing, even among the most intractable classes, with very little assistance from the law. He will, if necessary, wait and see a closet cleaned out by the proper person. Last year only a dozen or so of people were summoned for neglect in this

respect, and three of the offenders had to be sent to prison. It will be seen from the drawing that in connexion with these closets there is an opening of access to the trough and water supply. This opening is for the scavenger, and the people using the closets have no concern with it. The scavengers are employed by the Corporation, and every day they visit each of the trough closets, unlock the iron door of access, discharge the contents of the trough, flush it out with hose and water, sweep it thoroughly clean and leave it charged with fresh water for the next 24 hours' use. Frost has done no harm to these trough closets, nor yet to the ordinary siphon closet with its service box.

Liverpool.

"The ashes and other refuse of such houses and courts as have common closets on the trough principle are now put out on the street and carted away daily by the public scavengers. The throwing of ashes about the courts or into the privies is an offence, and under the efficient inspection that is given is becoming of rare occurrence; but where midden privies exist ashes and refuse are of course thrown into the midden-pit.

"There can be no question of the admirable efficiency of the working of the arrangements above described in semi-public privies, nor of the recognition by the people of the superiority of the new to the old arrangements. Nor can there be any question that these results are due even more to the management of the whole business by the public authority than to the excellence of the constructive arrangements themselves. And not only is complete freedom from nuisance obtained where formerly filth and stink were universal, but Dr. Trench states that in 1868, when an epidemic of enteric fever was prevailing in and about Liverpool 'the only localities that seemed exempt from it were 'the places occupied by the poor in which we had removed all the 'privies and made trough waterclosets.'"

Bristol.

Bristol (1871, population 182,552, inhabited houses 27,536).—The provision for excrement disposal in the poorer class of houses in Bristol is of peculiar interest. A privy has long been in use there which is, in fact, a watercloset flushed by hand. The privy in its present state appears to have grown out of some pre-existing usage of which the history has not been very definitely recorded; but the rules by which the construction of the privy are now regulated date from 1865. This privy is held by the medical officer of health for the borough, Dr. David Davies, to meet very efficiently the needs of the poorer classes of the population as to excrement disposal. It appeared to me desirable, therefore, in view of the adverse experience of this department to waterclosets flushed by hand, and to the numerous instances in which inquiry had been made by the department concerning mischief to health arising from such arrangement, to investigate the conditions under which this mode of excrement disposal worked successfully in Bristol. To this end Dr. Davies and the different inspectors of the city gave me ready assistance, and with their help I was enabled to contrast the working of the system in Bristol with its working in the neighbouring village of Westbury-on-Trym, which has recently come under the charge of Dr. Davies as medical officer of health for the newly formed sanitary district in which it stands, but which had not at the time of my visit been placed under detailed sanitary supervision.

The privy is required to be constructed according to the following rules:—

"The Bristol Local Board of Health will not consider any privy sufficient unless it be constructed in the following manner:—

"The trunk of the privy to be of brick work set in cement, and

rendered on the four inside faces with cement not less than one inch in thickness.

"The eject to be of freestone not larger than 18 inches long by 9 inches wide, and 12 inches deep, having the tongue standing at least 3 inches in the water.

"The drain to be of 9-inch stone-ware pipes properly laid and jointed, and with a fall of not less than 1 inch in 5 feet.

"The privy to be ventilated by means of an opening of not less than 9 inches square, communicating with the external air, and if the privy be situate in a dwelling-house and communication with the external air cannot be otherwise readily obtained, an air-tight trunk or shaft of not less than 9 inches square is to be provided and fixed.

"All the works to be executed as the Board's surveyor shall direct, and to his satisfaction."

A drawing of the arrangement of the privy is given in Plate XXXIV, and it will be observed that the "eject" forms a somewhat capacious dip-trap. The "eject" is now also constructed of stone-ware, and "ejects" of this material are permitted to be used in place of the freestone "eject." The advantages claimed for this kind of privy are its little liability to get out of order from careless use or from violence, and the facility with which foreign matters that may have been cast into it can be removed without damaging the structure.

I examined a considerable number of these privies in the poorer parts of the city, and among the population most liable to misuse them, and found with few exceptions the "ejects" free from accumulated matters and the "trunks" clean and without offence. On the other hand, I examined several privies in Westbury-on-Trym of similar construction, and found some of these blocked and the trunks filled almost to the brim with excrement, and others foul within and most offensive. In fact I found the privies here in the state in which I had been accustomed to find other forms of waterclosets elsewhere in which flushing by hand had been depended upon as a means of cleansing them. The difference in the state of the privies in Westbury-on-Trym and in Bristol indicated corresponding differences in supervision, management, and water supply.

In Westbury-on-Trym, to the time of my visit, the local authority had exercised no systematic supervision or control over the management of the privies, and such supervision and control has only now become possible since the sanitary organization formed under the Public Health Act, 1872; the water supply is scanty, and more or less labour is involved in carriage of the quantity of water to the privy needed for the purpose of flushing it; while the incidental help which might be derived from slop water is not uncommonly diverted from the privy by a drain with gully conveniently placed close to the cottage door. The excuse proffered for the state of the privy seen in worst condition was that "the husband came home too tired from his work at night to "undertake fetching pails of water with which to flush it."

In Bristol, as contrasted with this state of things, the Corporation maintains a constant systematic supervision over the privies, and by its servants undertakes the management and cleansing (even to lime washing the closets) of those situated in the worst districts, while the water supply is abundant and close at hand. Three conditions, indeed, are found necessary to the successful working of the Bristol privy, namely :—

1. Frequent systematic inspection.
2. The sanitary authority being prepared to cleanse, and undertaking the cleansing of the privies where necessary.
3. A plentiful and readily accessible supply of water.

Under these conditions the Bristol privy works well in Bristol, but in judging of its applicability elsewhere another highly important consideration should not be overlooked. The poorer population of Bristol which most needs, and indeed absolutely requires the active interference of the Corporation in its sanitary management, is for the most part housed in small houses which rarely contain more than two families. This gives great facility in dealing with individual houses and families, as regards excrement disposal, general sanitary management, and the control of infectious disease. The problem, in fact, of excrement disposal in Bristol is very different from that which presents itself in Liverpool and Glasgow. The number of families having access to a privy in Bristol obviously exercised a considerable influence upon the state in which it was found as to freedom or not from filth.

Bristol.

Bristol has four inspectors of nuisances to each of whom is attached two men. I accompanied one inspector on part of a round to observe the process of cleansing the privies which it was necessary the Corporation's servants should see to. The men were armed with a species of two-pronged iron rake used for the purpose of clearing blocked ejects, and they carried with them freshly slaked lime to sprinkle the "trunks" with. I observed that while a single bucketful of water sufficed to flush some "ejects," others required several bucketfuls. This inspection and cleansing is carried out at weekly or shorter intervals, according as the known necessity of the case requires. I should add that where the arrangement can be made, the rain-water pipes and yard drains are made to communicate with the ejects so as to secure the flushing action of rainfall and of the house slops.

Birkenhead.

Birkenhead.—I visited Birkenhead for the purpose of ascertaining the results of experience there in the working of *tumbler water-closets.* Mr. Francis Vacher, the Medical Officer of Health, courteously undertook to prepare a special report on the subject, which I here subjoin. This report is as thorough as suggestive, and it renders unnecessary any observations on my part.

Report on the experience of Birkenhead as to the working of the Tumbler Watercloset System, by Francis Vacher, Medical Officer of Health for the District.

"The tumbler watercloset, which is merely a trough closet flushed automatically by means of a water box which capsizes at regular intervals, was introduced into Birkenhead in October 1864, and since that date 40 have been constructed. In many instances they have replaced offensive middens or privies, in some they were designed with the houses they serve, and in two cases they were erected simply to flush the drains from ordinary hopper waterclosets. To a Mr. Matthews, the owner of a small cottage property in the humbler part of the town, the credit is due of having built the first tumbler closet, the idea having been suggested to him by the town surveyor, who was familiar with the system in use at Leeds. As this is one of the best, if not the best, closet of the kind in Birkenhead, I will briefly describe it. The trough is of brick built in cement and cemented over, round-bottomed with a slight fall, and made to retain 4 inches of water by means of a bar. Beyond the bar is a siphon trap protected by a grid. The trough receives from two seats each in a separate locked closet, and the tumbler is in a locked compartment adjoining. The length of the trough from mouth of tip to trough bar is 8 feet. The tumbler is of cast iron, the

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trunnions being cast in a piece with the box. The measurements are supplied to me as below:—

Length of tumbler at top			- -	3 ft.
Do.	do	at bottom	- -	1 ft. 10 in.
Width	do	"	- -	1 ft. 7⅝ in.
Depth	do	"	- -	1 ft. ⅜ in.

Trunnions are 6¼ in. from top, and 1 ft. 1¾ in. from back.

"The tumbler is set in a stout wooden frame built into brickwork, the trunnions riding in cast-iron grooves capped with cast iron. The water supply is direct by a ½-inch pipe fitted with a tap. The tumbler has never been out of order, and the owner only once had it out, and then for the purpose of removing an india-rubber bed that had been fixed to the back part of the frame, and which was not found to be an improvement. Mr. Matthews' double closet accommodates four cottages, the number of adults and children inhabiting which is now 24. Since it has been in use a man has always been paid to cleanse and take care of it.

"Nearly all the tumblers in the town are similar to this. I am told that at least half were cast from the same pattern. The dimensions of four or five that I took were a trifle less than the measurements given above. In some I noticed the trunnions had been riveted on, and a few were furnished with brass bushes. While, however, nearly all the tumblers put up in Birkenhead are alike in pattern and size, there is no sort of uniformity in the troughs they flush. Of the three next constructed (December 1864), one measures 13 feet, receives from four seats, and accommodates nine houses, lodging together 37 persons; the second measures 29 feet, receives from eight seats, and accommodates 14 houses, lodging 49 persons; and the third measures 130 feet, receives from 10 seats, and accommodates 10 houses, now lodging 68 persons. The 13-feet and 29-feet troughs are of brick cemented over, each very shallow at one end and deep at the other, and not rounded off, the bottoms forming two inclined planes. These troughs do not retain water, and there is nothing to prevent articles mischievously or carelessly consigned to them choking the 9-inch pipes they deliver into. It is therefore not surprising that during the last three years the condition of each of these tumbler closets has six times formed the subject of a nuisance removal notice. The 130-feet range referred to is a far more objectionable structure. It is not a trough at all, but a series of round-bottomed brick receptacles (neatly built but not cemented over), connected by means of 9-inch glazed earthenware pipes. On May 12th when I visited this row of closets they had just been cleansed, and the man who had been employed for the purpose drew my attention to a bucket of "foreign bodies" he had removed, among which were several large bits of broken crockery, a brick, a piece of cotton cloth, a scrubbing brush, a quart bottle, and an 8-oz. phial corked and labelled, containing medicine.

"Of the 10 tumblers erected in 1865, four deserve special notice. Two, already alluded to, are remarkable as having never served any further purpose than flushing the drains of eight ordinary waterclosets. One, placed at the end of a row of 12 hut closets in a common yard behind a back street (inasmuch as the tumbler and closets are accessible to anyone), is much misused; and the trough, though a fairly well-made one, frequently becomes obstructed. One designed to carry away the soil delivered through 15 seats, sends each charge of water along a line of 15 brick receptacles, connected by 9-inch pipes, pipes and receptacles measuring 185 feet. The population (taken this May) of the 15 houses thus accommodated was 110 all told. Out of the remaining six of the tumblers put up in 1865, only three tip into properly made water-

retaining cemented troughs; the other three, which serve respectively three, five, and five houses, tipping into three, five, and five receptacles, the three connected with 9-inch, and the five each with 12-inch pipes.

"There appear to have been eight tumbler closets constructed in 1866. Three of these were in connexion with property now in ruins, and about to be cleared away by a railway company; two are fairly made trough closets now in use (the trough of one, however, being twice bent at a right angle); one consists of six receptacles connected by and flowing into 9-inch pipes, one of five receptacles connected by and flowing into 6-inch pipes, and one consists of three large cesspits connected by and flowing into 12-inch pipes.

"This last I am desirous of drawing particular attention to. The extraordinary amount of work its projectors designed that one tumbler should achieve is hardly credible. It was to flush beneath 32 seats, accommodating 37 houses; the distance from mouth of tip to the end seat being 119 feet, and the population of the houses served (taken this May when some few were empty) being 191 adults and children. How one tumbler has accomplished such a task may be imagined. On seven separate occasions since June 1871, the owners of the range have been served with a nuisance removal notice in respect of its condition; the number of times it has been cleansed without the interference of the sanitary authority I of course have no means of telling.

"Of the tumbler closets put up in 1867, four have well-built cement-lined troughs, one measuring 73 feet, one 10 feet, and two 13 feet each. The latter pair are, however, not without defects; their tumblers being awkwardly placed, the oil holes in the trunnion caps almost inaccessible, and each of the troughs being L shaped. The only other tumbler range built in this year is unique in design. It consists of an arched brick sewer 60 feet long, into which six seats deliver by means of six roughly made man-holes, and is flushed by two tumblers.

"I find no record of any tumbler constructions in 1869, and only one pair of tumblers credited to 1869. One tumbler closet probably opened about this time, after being many times obstructed, and giving much trouble was last year converted into an ordinary trough closet. The 1869 pair are now in good working order; but when I exposed them a few weeks back (they had been carefully sealed up under two flagstones, as I take it, to prevent anyone tampering with them), they were tilted and fixed, and the closets in a disgustingly foul state.

"I am not able to give with any certainty of being correct the dates of erection of the remaining nine tumbler closet ranges in the township. One has been put up within the last few months, the others all appear to have been two or three years in use. Five are carefully made troughs varying in length from $7\frac{1}{2}$ to 68 feet; three are pipe-joined brick receptacles measuring severally 93, 93, and 51 feet, and one consists of two short troughs united by 9-inch pipes.

"As regards the water supply of these 40 tumbler closets, 16 only were constructed in connextion with cisterns (the three now in ruins being among those thus favoured), the remainder from first to last deriving their supply direct from the mains. Two are served by 1-inch pipes, seven or eight by $\frac{3}{4}$ or $\frac{5}{8}$ inches, and the rest by $\frac{1}{2}$-inch pipes. I mention this as it is a particular that should not be omitted in a statement of this kind; but practically the size of the supply-pipe is not very important, as I found by experiment a $\frac{1}{2}$-inch supply from the main will deliver 18 gallons in from four to seven minutes. Whether the supply is direct or by cistern is of course of paramount importance, as in the former case the tumblers are necessarily idle when the water is "off," in Birkenhead two days a week.

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" I have said that nearly all our tumblers are similar in size and pattern, with one exception (that in the girls' yard of the industrial schools, which measures 27 inches at the top by 16 inches at the bottom, 10 inches deep, and 13 inches across, and which falls at eight gallons); they are all nominally 21-gallon tumblers, but out of nine whose capacities I tested, only two required 21-gallon charges to capsize them, one capsizing at 20 gallons, three at 18 gallons, one at 17 gallons, and two at 15 gallons.

" Some, when I inspected them, were tipping every 20 minutes, some about hourly, and some apparently only every five or six hours, or less frequently. There is evidently no rule whether a tumbler is found capsizing three times an hour or three times a day, the frequency as often as not simply depending on the person who has last adjusted the tap serving it. When this kindly office has just been performed by a neighbouring house tenant, the tumbler is discovered to be working briskly, when by a waterman the reverse of briskly. For instance, on my directing attention to the mere trickling supplied to one tumbler, I was told by an occupant of the house behind which it was situated that " a man was at it the other day, and he thought it went too fast," and on my telling another house tenant what supply I considered the tumbler on his premises should have, I was answered, " The waterman comes round and he puts the tap slow."

" One tumbler I noticed very inadequately supplied with water had the ⅝ lead pipe delivering into it neatly flattened, so that it could do no more than dribble. Of course I cannot say the waterman did this, but it had without doubt been done designedly; yet the tenant in whose yard the tumbler receptacle stands assures me it was not done by him, and I am quite certain it was not the work of any servant of the sanitary authority.

" The tumblers in connexion with schools (except those at the industrial schools) are not kept working night and day, but merely during school hours, or as occasional flushing boxes. Thus the master at St. John's schools informed me the tumbler was only used at dinner time, and then made to fall three or four times; he attended to this himself to prevent waste, he naïvely added, as there was a meter against him. The man who had charge of the tumbler at Our Lady schools was, however, even more niggardly in the matter of water; he flushed with two tumblerfuls every evening, and this was all the water he used except on Saturdays, when he thoroughly cleansed tumbler and trough. The master of St. Lawrence's schools told me he " flushed once a day, or less frequently," but here the rain water helps the master occasionally, the spouting from the roof of this building being directed on to the tumbler.

" As regards the situations of our tumblers, these are not all well chosen. Some are underground and difficult of access; some so close to inhabited rooms that they must prove a source of annoyance, and one is uncomfortably near a seat. Then some instead of being set to face their troughs are at right angles to them, the result being that the force with which each charge of water is thrown is lost.

" Most of the tumblers are very properly housed in locked receptacles, but the locks on some are broken or out of order. Even a good padlock, however, will not always prevent an officious waterman from meddling. Thus, on my asking one of the tenants in Back Myrtle Street if she would obtain for me the tumbler door key, I was brought a poker for wrenching out the staple, at the same time being told, " This is what the waterman uses."

" In a period of nearly 10 years we have only put up 40 tumblers, and

only 12 since 1867. Of the 36 now in use, seven but serve as occasional flushing boxes, two merely assist in cleansing ordinary watercloset drains, and five (that in the park and those in the industrial schools and market vaults) are in places where closets of any kind could readily be kept in order. Thus an answer to the important question whether or not tumbler closets are adapted to the wants of the poor must rest, so far as the experience of Birkenhead goes, upon the evidence furnished by no more than 22 such closets. As these all, with a single exception, not unfrequently get out of gear, or become obstructed and cause nuisances, I cannot resist the conclusion that tumbler closets are not suitable at all events for the class of tenants for whom they have been provided in Birkenhead. The foregoing facts not only show the very limited extent of the tumbler experiment in this town, but also the still more limited success it has met with.

"Of course it may be said that the people referred to are peculiarly dirty in their habits. I do not think so; they are ordinary cottage property occupants, skilled and unskilled working men and their families, who pay rents averaging from 4*s.* to 8*s.* 6*d.* per week. But even if they were uncleanly above their fellows in other towns, do not the advocates of the tumbler-closet system contend that it is specially fitted for those who cannot be got to keep clean any form of pan watercloset? With more truth it may be urged that our tumbler ranges have never received the care and attention which is necessary to maintain them in thorough order; but if tumblers are to make the same demands on the time of the township's sanitary labourers as common trough closets it is difficult to understand wherein lies their special advantage.

"No doubt the failure (I am constrained to call it a failure) of the tumbler-closet system here is chiefly due to our ranges having been for the most part ill-planned, too long, and required to serve too many persons. The 23 now in use in connexion with cottage property have an aggregate length of 1,192 feet, receive from 152 seats, and accommodate 191 houses inhabited by 946 persons; thus the mean length per range is 54 feet; the average number of seats each range receives from, 6·9; the average number of houses served per range being 8·6, and the average number of persons 43. The folly of building ranges such as the following, it cannot be necessary to insist upon.

—	Length of Trough or Pipes.	No. of Seats.	No. of Houses accommodated.	No. of Persons accommodated.	
				Adults.	Children.
Oliver Place -	130 feet	10	10	30	38
Eldon Place -	185 „	15	15	57	53
Orderly Place -	119 „	32	37	86	105

"Of the 22 ranges only 6 are in my opinion fairly well constructed, and but one of these is supplied with a cistern.

"As regards the practice in some of our day schools of flushing their closets with a few tumblerfuls at noon, or after school hours, I have nothing to say against this as I have seen troughs thus kept very clean, especially those that get a brushing once a week; but such closets have no pretensions to be classed as genuine tumbler closets.

"The tumbler-closet system appears to me to be so perfect in theory, that I regret I am unable to give a more satisfactory report of my experience of it, and I am still in hopes other towns may be more successful with it than Birkenhead has been.

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"That the removal of excremental matter from districts occupied wholly by the working classes may yet be efficiently accomplished by means of tumbler closets I cannot doubt, provided only the closets be properly constructed and placed under careful supervision.

"In conclusion I take the liberty of submitting the following suggestions regarding the structure and management of tumbler closets :—

"I. *The tumbler*, of iron, cast in one piece, and to hold a charge of not less than 18 gallons, should be swung in a strong wooden frame set in brickwork, the trunnion caps being furnished with oil holes and pegs, the whole being in a locked compartment accessible only to the sanitary authority's accredited servant.

"II. *The channel* to be flushed should be a brickwork, cement-lined, open, straight trough, round bottomed, with slight incline, and made to retain water, at least 1 inch, at its shallow end. It should terminate in a syphon-trap protected by a grid, and should not measure more than 25 feet, or receive from more than 5 seats.

"III. *The seats* should be of wood, not painted, each in a separate locked compartment, each exclusively for the use of the occupiers of one house, and accessible only to the occupiers of one house and the sanitary authority's accredited servant.

"IV. *The water supply* should be by cistern, the capacity of each cistern not being less than 1,000 gallons (except in districts where the mains are always charged), and the service pipe should be fitted with a ferrule of a size to enable it to deliver not less than 18 gallons every 40 minutes.

"V. *Inspection* should be undertaken by the sanitary authority, and should be systematic, thorough, and frequent ; every tumbler, channel, seat, and cistern in a district being examined by a servant of the sanitary authority at least once a week."

Worksop.

WORKSOP (1871, population 10,409; inhabited houses 2,074).—I had reason to believe that I could study with advantage in operation at Worksop waterclosets flushed by hand with slops and waste water, and I visited that town for the purpose. I found, however, that the total number of waterclosets in the town did not exceed 90, and of these from 18 to 20 only were without cisterns. Other provision for excrement disposal consisted of the common midden closet. The surveyor and inspector of nuisances entertained a strong objection to the waterclosets without proper water supply, from the liability to blocking of the drains connected with them. I inspected 11 of these closets with the following results : in five the pans were very filthy ; in five others the pans were more or less smeared with excrement ; and in one only was the pan in a proper state of cleanliness.

THE DRY-EARTH SYSTEM.

Dry-Earth System.

The dry-earth system of excrement-disposal, designed and perfected by the Rev. Henry Moule, M.A., vicar of Fordington, Dorset, is best described in the words of Dr. Buchanan, given in his report of an official inquiry concerning the subject made in 1869. He writes as follows :—

"The dry-earth system consists in the application, with the greatest procurable detail, of dry earth to fresh human excrement, and in the subsequent removal and use of the mixture for agricultural purposes. In so far as detailed application is not made, or as the earth is not dry, or the excrement

not fresh, or the mixture otherwise dealt with, the dry-earth system is departed from.

Dry-Earth System.

"If about a pound and a half of suitable earth, carefully dried, be thrown over a dejection, all smell from it is forthwith removed, and if the same quantity be mixed with half a pint of urine the latter is absorbed. The mixture of earth with stool and urine is not only inoffensive when fresh, but remains so after keeping for two or three months, or longer.

"The process which goes on in the mixture is obviously one of disintegration and of some combination between the earth and the organic matter, as is evidenced by the disappearance of stools and even of paper among the other constituents of the compost. But the absence of fœtor from the mixture of earth with stool or urine, even with prolonged keeping, shows that decomposition in the ordinary sense does not take place.

"The Rev. H. Moule, to whose observations the practical use of these facts is due, regards the process which takes place in the mixture as consisting in a change of the organic substances of excrement into the state in which organic matter naturally exists in fertile soil, in such a way that the animal refuse becomes proximately available for the support of the plant, without undergoing ultimate reduction into simple salts and gases.

"In order that the described result shall be efficiently brought about, the quantity and quality of the earth have to be considered. With any quantity materially less than a pound and a half to the average dejection, (unless some artificial means, not generally applicable, of mixing are had recourse to,) a tendency to wetness remains, and more or less fœtor results. If much more earth is used the proportionate agricultural value of the product is lessened. The quality of earth, as affecting its power of producing an inoffensive compost with excrement, is of at least equal importance with its quantity. Sand and gravel have almost no power in this respect. Chalk has very little. Clay stands very high in rank. Properly dried it falls readily into a convenient powder which has great power of absorption and of preventing offensive change. High in rank also is surface earth, that which is loamy being preferable to any of peaty character. One of the best of all earths is the brick earth of the drift. Earths which already contain some quantity of organic matter are very suitable. Some one of these better sorts of earth may be readily procured in most parts of England.

"The mixture of excrement and earth appears to become more intimate after a little time has elapsed; for whereas the mixture when fresh will, if exposed to heat or wet, enter into ordinary decomposition and become fœtid, it may (if a proper proportion of good earth have been used), after remaining a month or so (during which time it gives off no offensive gases), be exposed to wet and to any moderate degree of heat without the production of any smell.

"I have next to mention a circumstance, of the truth of which I have complete evidence, both from the statements of those who have used the system and also from my own observation, but which was at first unexpected and surprising to me. It is that the mixture of excrement with earth, after being kept awhile and then dried, has again the power which the original earth possessed of absorbing and making inoffensive any stools and urine to which it is applied. This power is so marked that it has repeatedly been alleged to me that the earth (especially if clay) acts better a second time than the first, and I can answer from my own observation that earth used three and four times over, with drying at the proper stages, will render excrement quite inoffensive. The limits of this power do not appear to have been reached, but for experiment's sake the earth has been employed a dozen and more times over, when it must have come to have more than half its bulk of excrement, with the same result on the dejections as at first."

When Dr. Buchanan made his inquiry in 1869, certain debatable and some doubtful questions occupied much of his attention. So far as the present inquiry is concerned, but one of these questions needs consideration, namely, the extent of applicability of the system to communities.

Of the value of dry-earth as a means of abating excrement-nuisance no question, I presume, now exists; and its application in detail to

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this purpose has been facilitated to the utmost by the ingenious mechanical arrangements devised and patented by Mr. Moule and Mr. Girdlestone (the engineer of Moule's Earth-Closet Company). These arrangements, which provide for proper charges of dry-earth being thrown upon the deposited excrement, admit of ready adoption of the system in houses, schools, and other institutions.

Since Dr. Buchanan's inquiry the system, in its integrity, has been adopted in many mansions and on numerous estates, as well as in not a few public and private institutions. The wider experience of its use under these circumstances does not differ in result from that which has been already recorded by Dr. Buchanan, and it would serve no useful purpose to enter into a detailed examination here of the different instances which came under observation during this inquiry. So far as my observation went, wherever the system had been intelligently applied and carried out, and due supervision over its working had been maintained, there its success in the abatement of nuisance from and the disposal of excrement had been assured. Where the system had been adopted without due regard to the amount and kind of labour at disposal and the amount of supervision which could be secured, there it had failed, as any other system would have failed, under like circumstances. Other important sources of failure, so-called, cannot rightly be accredited to the system. The chief of these were imperfect preparation of the earth, and mixing with it, or substituting for it, dry coal ash. In several places I found that the so-called dry-earth system was a dry-ash system, and that the defects arising from the little else than mechanical action of dry coal-ash as a deodoriser were wrongfully spoken of as belonging to the dry-earth system.

The most interesting applications of the system which I observed during the inquiry were among certain mining and colliery villages in Yorkshire and Durham, and at the Industrious Aid Society's cottages and farm at Hereford.

At Sinningrove, a village on the sea coast, at the foot of the Cleveland Hills, and adjoining the Lofthouse iron-ore mines, I saw 66 earth-closets in operation. The mines are the property of Messrs. Pease, of Darlington, and the earth-closets had been introduced at the suggestion of Mr. France, the manager. The closets, of which the mechanism had been constructed by Moule's Earth-Closet Company, were in excellent order, and the earth supplied to them, a clayey soil obtained from the foundation of buildings, had been carefully dried in a proper kiln erected for the purpose. A few of the closets had lever-seats, in others the earth was cast from the hopper upon the excrement by a handle acting upon a simply arranged "chucker." A man was detailed to prepare the earth and keep the hoppers supplied; and an arrangement had been made with neighbouring farmers to remove the contents of the closets once in every three weeks. No difficulty had been experienced in making this arrangement; indeed, the farmers, it was told me, very gladly undertook the task for the value of the manure, and further, they had engaged to supply earth for the use of the closets when that obtained from new buildings failed. An inspection of the closets showed that the users had not habituated themselves to putting the mechanism in action after use, and that in consequence in some, although the hoppers were full of earth, the excrement was uncovered. This, however, appeared to have arisen rather from an oversight in the management than from any indisposition on the part of the cottagers to use the closets properly. It had been too readily assumed that the population for whom the closets were designed would take to their use without some instructional supervision. The advantages of the closet, as com-

pared with the old-fashioned midden-closet were, however, so obvious, even in the state that I saw them, that Mr. France was about to introduce 200 in a new mining village then in process of being built on the hills above Sinningrove.

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At the Adelaide collieries, Shildon (Bishop Auckland), also the property of Messrs. Pease, a row of cottages lately erected has been furnished with earth-closets. These closets, placed in the yards in rear of the cottages, are furnished with apparatus similar to that adopted at Sinningrove, as described in the foregoing section, and also prepared by Moule's Earth-Closet Company. The proprietors undertake the charge of supplying the closets with earth and removing their contents, the hoppers being filled weekly and the closets cleansed every three weeks, the contents being used upon a farm adjoining the colliery. The earth, a surface soil, is not specially dried, but simply placed for a time, and occasionally turned over, in a shed attached to a gas-house. The occupants of the cottages belong to the better class of colliers, the whole of their surroundings being characterised by comfort and orderliness. In almost every instance the closet was found to be in proper use, and the excrement covered with earth. A few had a little wet in them, but of these one or two only had any offensiveness, and in two, the contents of the hopper having become exhausted by an oversight of the filler, the excrement had been covered in one case by sand, in the other by ashes. The several cottagers to whom I spoke on the subject were, with one exception, enthusiastic in their preference for the earth-closet as compared with the old midden-closet, and more than one spoke of its greater decency, and of the influence of this upon the habits of growing children. In this respect, the instances I have just mentioned of the covering up of the excrement with ashes and sand when the earth failed, are instructive. One woman, however, expressed a decided preference for the old privy stink as compared with the new privy (earth-closet) stink. More specifically she complained that, unless she kept the closet door constantly open, there was at times a most disagreeable odour in the closet. The closet was one of the wet ones, and her complaint directed attention to the fact that no sufficient provision had been made for the ventilation of the closets.

The Hereford Society for Aiding the Industrious has 11 model cottages and a model farm on the outskirts of the city. The dry-earth system is in use here not only for the inhabitants of the cottages, but also for the piggeries and the fowl-pens; and the farm (9 acres) and plots of garden attached to each cottage (one-sixth of an acre) are wholly cultivated with the manure from the dry-earth closets, pig-styes, and fowl-pens. Some slight amount of sub-irrigation from house slops in the garden plots may be put out of consideration as aiding cultivation, from the limited extent to which the liquid is distributed in the irrigating drains. Each cottage has its arrangement for drying earth, but the rule of collection and preparation would appear to be to gather earth (a fine surface soil) in dry weather, and store for use, without artificial drying, sifting the fine earth from the coarse before charging the closet hoppers. The receptacles of the closets are built of brick, and cemented within. They measure 2 feet 6 inches by 4 feet, and 3 feet 6 inches in depth. The contents are removed twice or thrice yearly by the cottagers, according to the fulness of receptacle, or to garden requirements, as the case may be. I noticed here, as also at Halton, that several receptacles had within them a large number of small flies. Frequent insufficient covering of the excrement, from the use of the closet by children, might have something to do with this phenomenon.

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The dry-earth is passed three times through the closets which serve for this purpose to form manure for the farm; but in the piggeries and fowl-pens the dry-earth is used once only. Each cottage has its pigstye and large fowl-pen, and on the farm a great range of pigstyes and fowl-pens has been built, with mushroom- and rhubarb-forcing cellars beneath, of admirable construction and design. A layer of dry-earth, of from two to three inches in thickness, is spread at the bottom of each fowl house; this is raked over every morning, the upper surface being removed, and the earth is replaced as often as necessary. The floor of the outer portion of the pigstye is laid with a slight fall to a depression or gutter. Into this depression the urine flows, and the filth is swept several times a day, all being covered up with dry-earth. The cottagers are encouraged to follow the same practice with their pigs and fowls.

The earth-closets I examined were well managed, and the dry-earth appeared to be equally effectual in obviating nuisance from the excremental matters of pigs and fowls as of human beings.

I may note here that Mr. James, of Halton, pointed out to me a very useful application of the dry-earth system to cats. It would appear that cats take readily to an open box or other receptacle charged with dry-earth, and that this affords an excellent means of obviating the nuisance they are apt to create.

The statements made to me by Mr. Walters, the manager of the farm, of the great agricultural value of the earth-closet manure, accorded with statements I had already heard to the same effect from the Rev. Mr. Moule, Mr. James, of Halton, and Capt. Armytage, of the West Riding prison. Mr. Walters had a ready sale for the earth-closet manure, in small quantities, for garden purposes, at the rate of 6*s.* per cwt., and sales to the extent of between two and three tons had been effected at this price during the preceding 12 months. What part the earth-closet manure and the mode of cultivation respectively played in the agricultural successes Mr. Walters described to me, I am unable to judge, but it was impossible not to be struck by the detailed care given by him to his different farming and garden operations.

With the exception of the Corporation of Edinburgh, which has recently introduced public earth-closets into that city, as described in a previous section (p. 157), the Corporation of Lancaster is still, as at the time of Dr. Buchanan's inquiry, the sole sanitary authority (so far as transpired during this inquiry), which has adopted the dry-earth system; and in this case the adoption is only partial. When Dr. Buchanan visited Lancaster, 90 earth latrines, serving for 200 privies and 450 houses, were under the control of the Corporation. The number of earth latrines is now 120, including the latrines serving for a large school, and the houses thus provided for number about 500. The dry-earth system, although continued within these limits by the Corporation, is not now being extended. For new houses waterclosets are adopted The latrines are mainly old middensteads roofed in. The dry earth is stored up in one part and replenished from time to time. Once a day a servant of the Corporation visits the latrine and shovels over the excrement and urine deposited since his last visit a sufficient quantity of dry earth. The quantity of dry earth used weekly for the latrines amounts to 22 loads, each load weighing from 23 to 24 cwts. The earth is obtained from the foundations of new buildings, and about 18 months' stock is in store. Street sweepings are occasionally substituted for or used with it. At the time of my recent visit, street sweepings were alone in use, on account of the apparatus for drying earth being temporarily out of order. The contents are removed every six or seven weeks, and carted to the

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Corporation yard, where they are mixed up with blood offal from the shambles and street sweepings, and stacked in an open shed until required by the farmers. It was reported in 1869 that subsequent processes of preparation were adopted of a kind that formed no part of the earth system proper; but in 1869 these processes were at least carried out at such a distance from the town as not to create a nuisance. Now, in the Corporation yard, they are effected in close and very improper proximity to houses. At the time of my visit a great pile of the manure, giving off a pungent offensive odour, was awaiting sale. In 1869 the manure sold for from 7*s*. 6*d*. to 10*s*. the ton. The selling price is now 3*s*. a ton, and this fact, as well as the consideration that the time will probably come before long when earth must be bought for the latrines, instead of as now being simply obtained for the cost of carting, has no doubt largely influenced the judgment of the Corporation in ceasing to extend the dry-earth system. The sanitary gain from the latrines, measured by diminution of excrement nuisance and as compared with the old middenstead, is very considerable.

The dry-earth system, as practised at Lancaster, was introduced into that city, with the approval of the Corporation, by a gentleman since deceased; the Corporation subsequently adopting and extending very slightly, the system as first put into operation. The dry-earth system here is not a fair representation of that system as originally designed and intended to be carried out; and the history of its introduction and the method of management do not furnish such information as is to be desired for sanitary authorities regarding the adaptability of the system to the needs of a community in relation to excrement disposal. It may be taken that the system fully meets the requirements in this respect of certain kinds of institutions and of certain communities living on estates, or in connexion with mines or manufactories, under private management. But the question of adaptation of the system to a mixed community, for which the local authority must devise and carry out provisions for its sanitary welfare, has yet to be solved practically. It must not be too hastily assumed that the very fact of no local authority having adopted, of its own motion, the dry-earth system during the several years it has been before the public, is decisive against its adaptability to public requirements as to excrement disposal. The truth is, that only now does such a local sanitary organisation exist as would admit of its application in those villages and towns where presumably the system is best fitted for operation. Before the Public Health Act, 1872, the sanitary organisation of rural districts and of many small towns was too incomplete to give any reasonable hope of the efficient working of a system, whether the dry-earth or any other, which required careful and systematic supervision and management. Since the passing of that Act, an organisation fitted to these ends has either been established, or is in progress of establishment, in every part of the kingdom. It is, perhaps, even more necessary now than when Dr. Buchanan reported, that sanitary authorities, in examining the sanitary requirements of their districts, should have under their consideration the dry-earth system among other systems of dealing with excrement nuisances.

I have already mentioned the great value assigned to the earth-closet manure by certain gentlemen who are well acquainted with its practical use. This opinion, held also when Dr. Buchanan made his inquiry, has undergone no change, but has been confirmed by the five years additional experience since that inquiry took place. On the other hand Drs. Gilbert and Voelcker, studying the question chemically, have shown that the earth-closet manure after it has been charged twice, or even

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thrice, with excrement is no richer than good garden mould.* Mr. Walters, as I have stated, gets 6*l.* a ton for the manure retailed in small quantities, and I may add, that he believes this sum fairly represents the value of the material. Dr. Voelcker estimates the value of the compost after it has been charged five times with excrement at 7*s.* 6*d.* per ton. I cannot pretend to reconcile the differences; I merely state the facts. But it may be observed that the chemical estimate of the value of earth closet manure, does not disprove the sanitary value of the dry-earth system, but, so far as it may be the true index of value, only tends to shew that its economical adaptation must be limited to cottages and small towns, where the cost of providing and drying the earth and distribution of the manure will be of the smallest. On this question, the Committee on the Treatment and Utilization of Sewage appointed by the British Association for the Advancement of Science has said, as to houses and villages (again looking at the value as a matter to be estimated by chemical analysis), that the dry-earth system "might be even "economical where the earth for preparation and absorption and the land "for utilization, are in close proximity."†

Without desiring to under-rate the commercial aspects of the question, it appears to me that it is the economical aspect in the sense of obtaining an unquestioned good at the least cost which has place here. If the value of a method of excrement-disposal is to be estimated by its profitableness as a pecuniary investment, rather than by its hygienic success, all measures at present in use in this country would have to be condemned. From the former stand-point the best, perhaps, that can yet

* I give the following analysis, one of several showing similar results, by Dr. Voelcker:—

Composition of Earth and of three Samples of Earth-closet Manure produced at West Riding Prison, Wakefield, in dry state (dried at 212° Fah.).

—	No. 1. Earth for use in Closets.	No. 2. Earth once used in Closets.	No. 3. Earth twice used in Closets.	No. 4. Earth thrice used in Closets.
Organic matter and water of combination	9·88	9·79	11·53	12·22
Oxide of iron and alumina	12·95	16·15	14·11	12·48
Phosphoric acid	·18	·25	·44	·51
Carbonate of lime	2·21	2·25	2·13	2·14
Magnesia	1·44	2·63	·77	·90
Alkalies and loss in analysis	1·35		·72	·74
Insoluble siliceous matter (clay and sand)	71·99	68·93	70·30	71·01
	100·00	100·00	100·00	100·00
Containing nitrogen	·31	·37	·42	·51
Equal to ammonia	·37	·45	·51	·62

* "On the Composition and Agricultural Value of Earth-closet Manure." "Journal of the Royal Agricultural Society," No. 15, p. 185 (1872).

† Report, 1872, p. 188. Drs. Gilbert and Voelcker were both members of this Committee.

be said of the completest of these is, that it is the least costly. From the sanitary stand-point it is unfortunate, although quite explicable, that the promoters of the dry-earth system should have rested its advantages so largely upon its presumed results for agricultural purposes. Their experience must, however, be taken as showing that there are certain conditions of use of earth-closet manure which justify their enconiums of it as a manure; and there is no sufficient reason to believe that a multiplication of like experience would lead to different results. But adopting the chemical estimate of the value of earth-closet manure, it still leaves the question in this not particularly unfavourable position, namely, that the dry-earth system is perhaps the only method of excrement-disposal at present practised in this kingdom, which wholly or almost wholly would probably cover the cost of working, if it were judiciously put in operation within suitable districts.

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Thus regarded, Dr. Buchanan's estimate of the conditions and cost of application of the system to a community of 1,000 persons is as instructive now as when written, and I reproduce it with a few modifications and with the omission of that portion which relates to the estimated value of the manure.

"I now find myself in a position to state, with some approach to accuracy, the way in which the earth system may be worked, as well as its approximate cost and produce. I need not here consider the case of public institutions or of very small villages, as the instances quoted sufficiently illustrate the operation of the system there. But for my present purpose I begin with the case of a village population of 1,000 persons already provided with the ordinary arrangement of outside privies and cesspools. People making use of closets as receptacles for all stools and urine from every inhabitant, may be taken to use them on an average three times a day each,* and to require for each use 1½ lb. of dry earth. This gives 4,500 lbs., or two tons, as the daily quantity of earth required for the population. The amount that would accumulate in the closet pits, and which would need to be removed about four times a year, would be larger than this by the bulk of the stools and of such portion of urine as did not evaporate; but without reckoning increase on this score, the quantity of manure produced may be reckoned at the same quantity of two tons a week.

"I assume that, after owners of property have paid the original cost of providing earth-closets according to the scheme of the local authority, all supply and maintenance of them should be the function of that authority. The cost to owners would vary (1) according to the adaptability of the existing arrangements, and (2) according to the character of the earth arrangements to be required. The latter may either consist, as at Lancaster, in a single daily application of earth to the closets, or much preferably, as at Halton, in an arrangement for the mechanical delivery of earth after each use of the closet. In this latter case an average outlay for structural alterations and machinery of some 3*l.* or 4*l.* might be required in respect of each closet.

Expenses in a village.

"The expenses which, for the efficient management of the earth-closets of such a population, would have to be borne by the local authority, consist first in an original expenditure of some 250*l.*, and in a continuous weekly expenditure of about 4*l.* 15*s.*, as follows:—

Agricultural value.

	£	*s.*	*d.*
Capital:—			
Drying sheds and furnace - - - -	150	0	0
Cart and horse - - - - - - -	50	0	0
Other outlay - - - - - - -	50	0	0
Two men's wages, at 16*s.* - - - - -	1	12	0
One boy's wages - - - - - -	0	10	0
Horse keep - - - - - - - -	0	18	0
Firing (at 1*s.* 6*d.* for each ton of earth) - -	1	1	0
Purchase of earth (at 1*s.* a load) - - -	0	14	0

* "Closets used in the ordinary way, for stools and part of urine only, would not be so often visited. Less than two visits daily by the average person would be estimated for such use."

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The two men and boy could perfectly well manage the collection of earth, its drying and distribution, and the removal of the product, not only for our village of 1,000 inhabitants, but for a place, if lying compactly, of a hundred or two more.

"The annual cost to the authorities then would be (52 × 4*l.* 15*s.*) 247*l.*, and with the addition of 13*l.* as interest on capital, 260*l.* The removal of ashes might very well come within this amount, for if the labour of collecting were somewhat increased, there would be a saving in fuel by the gain of the cinders, and also a gain (to which little importance, however, attaches) of dry dust that might, in some circumstances, be used with the earth to the closets.

"The quantity of manure got from the earth-closets of the village would each year amount to 730 tons, or, from the consideration before advanced, more. The cost of production of this will have been 7*s.* a ton. . . . .

"This then is the way in which it appears that the earth system may best be worked in the village or small town. But it is susceptible of some modifications. For instance, if it be desired to irrigate partially with the refuse of the inhabitants, a part of the urine may be allowed to flow into sewers, or it may be wished to use some of the liquid refuse direct on cottage gardens; and, of course, in such cases less manure (at less cost) will be got from earth closets. And there appears no reason why an earth system should not be used in certain parts of a town, and a watercloset system in other parts. Especially when one remembers what a delicate machine the watercloset is, the use of the earth system may prove to be particularly useful for the poorer parts.

"The extension of this scheme beyond the village of 1,000 people to larger towns appears to be essentially a question of multiplication, with these differences: on the one hand, an organization on a large scale can commonly be had more cheaply than one on a small scale, and in this way and by its compactness the town has the advantage over the village; on the other hand, labour is dearer in towns, and towns often have their closets so arranged that it is difficult without much cost to adapt them to the earth system, and thus the village has advantage over the town. Further, in towns, which must necessarily be supplied with sewers for the purpose of drying the soil, and for removing rainfall and house slops, the question arises whether it may not be more advantageous to throw all foul matters together into these sewers. I do not propose to discuss the relative merits of a watercloset system and of an earth-closet system; this must depend upon a variety of considerations proper to each particular place. In a locality where sewage can be cheaply delivered upon suitably situated land, where the amount of sewage dilution is such as fits it for the particular crops that are marketable, where the irrigable land is of such extent and quality as effectually to remove the manurial constituents of sewage, and to allow of the effluent water passing off in sufficient purity; in short where sewage irrigation can be effected with profit to the people and safety to the health of themselves and their neighbours, I should anticipate a preference for a system of water carriage for the excrement of the place. But for populations where these conditions may not be attainable, or where experience may show greater profit realizable from solid manure, I should suppose that the earth system would find advocates in preference to the water system; and it is impossible to ignore the fact that many large English towns do not regard the watercloset system as suited to all their particular wants, nor irrigation as being a remedy certainly suitable to their particular sewerage difficulties. I refer, of course, to towns which, although possessed of a system of sewers, nevertheless retain their excrement in middens or cesspools, deliberately avoiding waterclosets as not affording them the certainty of advantage which they need to have before they enter upon expensive new constructions. By the authorities of such towns the earth system will especially deserve consideration as promising them the means of making harmless their retained excrement by a system readily, perhaps, adaptable to their present privy construction, and not involving in its introduction a new kind of difficulty."

The present inquiry has led me to conclusions as to the hygienic

advantages of the dry-earth system similar to those arrived at by Dr. Buchanan in 1869, and I adopt mainly his words in stating them.

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(1.) The earth-closet, intelligently managed, furnishes a means of disposing of excrement without nuisance, and apparently without detriment to health.

(2.) In communities, the earth-closet system requires to be managed by the authority of the place, and in limited communities it will probably pay at least the expenses of its management.

(3.) In the poorer class of houses, where supervision of any closet arrangements is indispensable, the adoption of the earth system offers especial advantages.

(4.) The earth system of excrement removal does not supersede the necessity for an independent means of removing slops, rain water, and soil water.

(6.) As compared with the watercloset, the earth-closet has these advantages :—It is cheaper in original cost ; it requires less repair ; it is not injured by frost ; it is not damaged by improper substances being thrown down it, and it very greatly reduces the quantity of water required by each household.

Note.—In the course of the present inquiry, an instance came to my knowledge of disease occurring in a place where earth closets were used, namely, certain states of ill health and an outbreak of enteric fever in the West Riding gaol, Wakefield, which the medical officer, Dr. Wood, believed to have been connected to some extent with the use of earth-closets there.

The *West Riding Prison*, Wakefield, has for eight years had numerous earth-closets in operation within it. The provision for the excrement-disposal of the prisoners confined there consists now of earth-closets and waterclosets in equal proportions, the number of each form of closet being about 800. The arrangements for drying the earth, preparing it for the closets, and for subsequently storing the contents of the used closets, are the most complete I have seen in any institution. The dry earth, before being distributed to the closets, is sifted through a sieve having a ¼-inch mesh. Formerly, closets with lever-action seats were used, but now the simpler arrangement of a scoop for covering the deposited excrement with the dried earth is in use throughout the prison. On the male side the prisoners are instructed not to pass their urine into the closets, but to use for the purpose a separate vessel. This urine was not, at the time of my visit, mixed with the compost removed from the closets, but was sold for scouring to blanket manufacturers. The average duration of the confinement of a prisoner in this prison is 53 days ; the maximum duration two years.

In November, 1870, enteric fever appeared in the prison. From a detailed report on the subject, which has been courteously forwarded to me by Dr. Wood, the medical officer, it appears that this malady had been so long unknown in the cells that it was almost a "new disease" within them. Seven cases of the disease took place in November, two in December, five in January, 1871, and three in February, after which month there were no further cases. Eighteen cases occurred altogether, of which 13 happened in the male division of the old prison buildings (the E. prison), four in three of the four wings of the new prison buildings,

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wholly devoted to males; (two in B. wing; one in C. wing; and one in A. wing); and one case occurred in December, in the reception cells. The origin of the outbreak was obscure, but it was believed to be connected with the prison itself, all the prisoners first attacked having been several months in confinement. The first case of enteric fever had occurred on the 21st October in the new buldings, the person attacked having entered the prison on the 21st March. The four next cases occurred in rapid succession (one on the 22d November, two on the 24th, and one on the 26th) in the old buildings among prisoners who had been in the prison 2, 4, 7, and 10 months respectively.* The outbreak took place at a time when there had been considerable deterioration of the prisoners' health in certain parts of the prison, believed to have arisen partly from deficiencies in the dietary then in force, partly from defects in the ventilation of certain parts of the prison, and partly from the mode of managing the earth-closets. The contents of the earth-closets at this period were removed from the cells only once a week, and it is stated to me that before the expiration of this time the cell was very commonly pervaded by a faint, unpleasant odour, coming from the mixed earth and excrement, and which no care in covering the excrement with abundant earth entirely obviated. It was believed that the enteric fever, and especially its localisation, was connected with the presence in a notable degree of the several conditions of unwholesomeness mentioned; and that in the older buildings of the prison (the E. prison where 13 of the 18 cases of fever occurred) the state of the water supply, obtained from a surface-well within the precincts, might have contributed to the localization.

A sub-committee of the magistrates investigated the different conditions of unwholesomeness referred to, and in April 1871, as the results of its deliberations, the water supplied to the prison (and which had been shewn by chemical analysis to be impure) was discontinued, and a supply from a purer source introduced; necessary changes in ventilation and warming of the unwholesome cells were carried out; the effects of the sparer dietary of the early period of imprisonment were more closely watched; and the following changes were directed to be made in the regulation of the earth-closets:—

19th April, 1871.—"That the pans in the earth-closets be emptied and

* The dates of admission into the prison and into the hospital of the several cases of enteric fever were as follows:

Order of Cases of Enteric Fever.	Dates of Admission.		Order of Cases of Enteric Fever.	Dates of Admission.	
	Prison.	Hospital.		Prison.	Hospital.
1	March 11/70.	Nov. 21/70.	9	Aug. 10/70.	Dec. 11/70.
2	Sept. 17 „	„ 22 „	10	Dec. 16 „	„ 19 „
3	Aug. 24 „	„ 24 „	11	Nov. 23 „	Jan. 12/71.
4	Jan. 6 „	„ 24 „	12	Nov. 26 „	„ 12 „
5	April 4 „	„ 26 „	13	Aug. 10 „	„ 12 „
6	May 24/69	„ 27 „	14	Jan. 2/71.	„ 18 „
7	Oct. 3/70.	„ 28 „	15	Jan. 13 „	„ 22 „
8	June 27 „	Dec. 2 „	16	April 20 „	Feb. 8 „

In addition, two prisoners from Coldbath Fields prison were admitted into hospital Feb. 15th and Feb. 17th respectively, but with enteric fever; the dates of admission of these prisoners into the West Riding prison are not stated.

" cleaned at least three times a week. That the earth be not used more than " once in the closets in the cells. That a scoop be supplied to each cell to be " used by prisoners in case of any defective or insufficient action in the " machinery of the closets. That earth after being used in closets, be not dried " in the present drying house, situate in the A. courtyard of the prison, and " which they recommend be used for drying clean earth only. That printed " instructions for the use of the closets be placed in each cell, and the neglect " of them treated as a breach of prison rules, and that the closets be frequently " inspected by officers of the prison as to their observance."

The enteric fever had ceased before these various changes were made, the last case having been admitted into hospital on the 17th February. Since the alterations the general health of the prisoners has improved; there has been no occurrence of enteric fever, and the working of the dry-earth system appears to give rise to no greater offensiveness in the cells than the watercloset system. During an inspection I made the number of instances of carelessness in the use of the earth-closets and of waterclosets which came under observation was about the same, but the offence seemed to me more obvious from the watercloset than the earth-closet.

This account of the presumed connexion of the outbreak of enteric fever described, with, among other conditions, defective working of the dry-earth system, I have given from the reports of Dr. Wood, written at the time. The progress of the outbreak and the circumstances under which it occurred, do not suggest to me other than an incidental connexion of the unwholesome conditions referred to with the enteric fever. Information is wanting as to the prevalence, at the time of the outbreak, of enteric fever in the town of Wakefield, and especially among houses in the immediate vicinity of the prison, situated above the stratum of ground from which the polluted well derived its water. When I inspected Wakefield in 1869, under instructions from the Privy Council, the people living in those houses deposited their excrement, as the people living there now still deposit it, in old privy-pits sunk into this stratum. Dr. Wood took objection to the management of the earth-closets, at the time of the outbreak, rather than to the dry-earth system. Of the present management of the closets in the prison, he remarks in a letter addressed to me on the subject: "As regards the earth-closets, with the " supervision we now have, I can urge no objection to them pro- " fessionally."

When Dr. Buchanan made his inquiry in 1869 as to the dry-earth system he gave consideration to the great prevalence of diarrhœa in the camp at Wimbledon, during the meeting of volunteers in the exceptionally hot summer of 1868, and which was held by some to have arisen from the use of earth-closets in the camp. It was shown by Dr. Buchanan that this prevalence was not local, but was part of a general prevalence, common to the camp and the whole of the metropolis, and that therefore the assumed connexion with the use of earth-closets could not be sustained. I visited the camp during the present inquiry, and the following table, prepared from figures courteously furnished to me by Staff-surgeon Owen, the principal medical officer, and showing the amount of diarrhœa at each of the Wimbledon meetings from 1868 to 1874, is of interest. The use of earth-closets in the camp has been continued from year to year, and when I inspected them on the eleventh day of the present year's meeting (1874), the working of the closets in

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Dry-Earth System.

the volunteer encampments, under the charge of Moule's Earth-closet Company, was admirable * :—

Force.	Wimbledon Camp.													
	1868.		1869.		1870.		1871.		1872.		1873.		1874.	
	Strength.	Diarrhœa.	Strength.	Diarrhœa.	Strength.	Diarrhœa.	Strength.	Diarrhœa.	Strength.	Diarrhœa.	Strength.	Diarrhœa.	Strength.	Diarrhœa.
Army -	548	41	670	0	655	3	400	2	633	1	607	1	643	1
Volunteers -	1,172	173	1,071	33	1,177	21	1,206	7	1,477	10	1,265	7	1,654	1
Police -	232	45	265	8	248	3	256	3	265	3	248	0	248	1
Camp Followers -	207	50	419	18	75	3	441	4	262	7	577	1	464	—
Totals -	2,159	309	2,425	59	2,155	30	2,303	16	2,637	21	2,697	9	3,009	3

III.—The Charcoal System.

Charcoal System.

The use of charcoal for deodorising, and subsequently disposing of excrement, came under observation during the inquiry in connexion with the operations of two commercial companies. One of these companies is the *Universal Charcoal and Sewage Company, Limited,* and the other the *Carbon Fertilizer Company, Limited.*

The Universal Charcoal and Sewage Company has works at Salford, in the town's yard, where it manufactures a charcoal from street sweepings. This charcoal, applicable to the various sanitary purposes to which charcoal can be put, is not used in detail in the deodorisation of privies in Salford; but I had an opportunity of judging of its deodorising effects on excrement in the manufacture of manure from mixed excrement and charcoal which is carried on at the works of the Company. The deodorization is complete, but as the operations of the Company do not include the abatement of excrement nuisance in privies, although it contemplates the charcoal, from its peculiar cheapness, being put to this use, and seeks a market for this purpose, any further description of the Company's objects and work do not enter into my inquiry.

The Carbon Fertilizer Company also manufactures a cheap charcoal from seaweed, but in addition it uses this in a defined way for the abatement of excrement nuisance, and for the utilization of the excre-

* The dry-earth system had been adopted throughout the *Broadmoor Criminal Lunatic Asylum,* shortly before Dr. Buchanan's inquiry, in consequence of continued prevalence among the inmates of a peculiar form of "fever" so-called, supposed at first to have been dependent partly on defective sewerage arrangements, and partly on a water supply containing much vegetable organic matter. At the time of Dr. Buchanan's visit, the probability of defective sewerage having any part in the prevalence was believed to have been entirely set aside, and as his report shows, the nature and origin of the disease remained in obscurity. I am now able to state that, subsequently to Dr. Buchanan's inquiry, further doubts arising as to the sewerage of the asylum, and the "fever" persisting, a more searching examination was made, and defects so extensive discovered, that it was found necessary to reconstruct a considerable portion of the drains. With this reconstruction the recurrence of the "fever" ceased, and no cases have been recorded since 1870.

Charcoal System

ment on a particular system. This system includes the charring of the excrement, after its first treatment with seaweed charcoal, so that the excrement itself may be made available in removing nuisance from excrement, and profitable as well in this way as from the chemical products distilled from it in the process of charring, or it may be converted into a valuable manure, or may be used in both these ways as proves best. The charcoal derived from the mixed charcoal and excrement is called by Mr. Edwd. C. C. Stanford, F.C.S., the inventor of the process, *Cycle*, or *X charcoal.* It increases in weight at each reburning by the amount obtained from the excrement; and it retains all the potash and phosphates of the excrement. From the volatilized products which pass off during the charring, and which include an inflammable gas of considerable illuminating powers, are condensed ammoniacal liquor and tar ; and from the ammoniacal liquor sulphate of ammonia and acetate of potash are obtained. The cycle charcoal, although wanting nitrogen, has a high estimated value as manure, and when charged with the ammonia distilled from it during charring forms a manure of double the estimated value in its former state, and designated by the Company "nitro-carbon manure."

My observations were necessarily limited to the action of the seaweed charcoal as used for deodorizing excrement. The proportions of water, carbon, and ash in this charcoal as compared with wood and bone charcoal are thus given by Mr. Stanford :—

	Wood.	Sea-weed.	Bone.
Water - -	6·2	2·6	3·0
Carbon - -	92·0	63·0	9·2
Ash - -	1·8	34·0	87·8

Mr. Stanford observes on these results that seaweed charcoal resembles more the charcoal from bone than from wood, but that it differs from bone charcoal in containing more carbon and carbonates of calcium and magnesium, and less phosphates of these bases. It is noteworthy that in Mr. Stanford's experiments no difference was observed in the action of wood charcoal and bone charcoal upon organic matter, notwithstanding the great difference in the proportion of carbon in them.

I examined the action of the seaweed charcoal as applied to excrement under the following conditions :—

1. *Works of the company at Dalmuir* :—(*a*) A closet attached to the office, used regularly by six or seven adult men, of which the receptacle had not been emptied for 2½ years. This receptacle received the whole of the excrement and the greater portion of the urine, during business hours, of the persons referred to. The seat of the closet has a lever action, and on each use an ingeniously designed "chucker," fed from a hopper, scatters a suitable proportion of charcoal over the deposited excrement. A urinal is also placed in the closet, of which the basin is filled with charcoal, and which communicates with the closet receptacle. The receptacle was opened for my inspection. All excrement was completely covered, and the contents were dry and odourless. The contents were freely turned over with a spade at my desire, but no odour was given off during the process. (*b*) Twelve months' accumulation in a large shed of mixed charcoal and excrement of about equal bulks, from closets in various manufactories and houses on the Clyde and in Glasgow. This great mass was quite odourless, and a section cut into it showed excrement retaining its form and unchanged paper, but without a trace of smell.

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(*c*) Another accumulation of mixed charcoal and excrement, which had been brought into the works a week before. This accumulation had a slight ammoniacal odour.

2. *Messrs. J. and G. Thomson's Ship Yard, Clyde Bank.* A privy of 36 seats, opening into a common vault, and used by 2,500 workers. The vault constitutes a chamber, entered by folding doors on the level of the ground, the closets forming a storey above, approached by stairs. The rule appears to be not to empty the contents of the vault until they approach the ceiling. At the time of my visit the vault was being cleared, and half the contents had been removed, leaving a section of the undisturbed half extending from floor to ceiling. Notwithstanding this newly exposed surface of the still great mass, there was no offensive odour, except in one or two spots where from careless use of closet, or an empty hopper, a portion of uncovered fresh excrement lay. The mechanism of the closets was similar to that already described.

3. *Smallpox Hospital, Glasgow.*—Here the charcoal is used with pail-closets, and for the close-stools in the wards. In the closets a box with scoop is placed on the seat, and the nurse is held responsible for covering the excrement deposited. Where this was properly done, the deodorization was complete. The use of the charcoal in the close-stool was said to be to some extent objectionable, from the difficulty of cleansing the vessels after its use, and from the amount of slop arising from this process which had to be cast into the closet-pail. The contents of the pails are deposited in a shed within the hospital inclosure, and removed at intervals of three weeks to Dalmuir. The deposit in the shed at the time of my visit was odourless, but moist when turned over. The hospital contained 100 patients, and 26 cwts. of charcoal were supplied to it twice a week. This was abundant for the requirements of this number of patients, but when the number had exceeded 200, some little difficulty had been experienced in obtaining a sufficient supply of charcoal.

4. *Bowling-Green Terrace, Glasgow, Stair,* No. 4.—The closets in this and adjoining stairs in the terrace have been built to communicate by shafts (a filthy arrangement) with a common receptacle in the basement. They were designed for dry-ash closets , and the closets of one stair have been converted into charcoal closets. Although the mechanism of one closet was broken, and the closets were dirty, there was no excremental smell from the shafts. But the inhabitants of the stairs complained of occasional smell when the receptacle had been long unemptied. The receptacle of the ash closets on an adjoining stair, it must be stated, was also almost free from smell, other than that of the ashes and dry-house refuse.

5. *The Quay, Glasgow.*—Two large public closets, one a Macfarlane's trough, without water, cleansed every alternate day; the other managed with charcoal, and containing a great accumulation in its pit. The former closet stunk unbearably, the latter had only such stink as came from excrement deposited since the last distribution of charcoal by the man in charge, this being effected several times daily. The former in fact was a public nuisance, the latter an unnoticeable convenience.

The quantity of charcoal needed for the efficient deodorization of excrement is stated to be by weight one-fourth that of dry earth; and upon this estimate the supplies of the Company to the various closets to which they furnish charcoal have been calculated. Mr. Stanford, taking the total excremental matters to be removed per

head from a household annually to be 8 cwts. (of which ¾ cwt. would be solid excrement), estimates that the quantity of charcoal required for the deodorization and utilization of a family of 10 persons would be about 4 tons yearly, and that the amount of material to be removed, making allowance for drying of the mixed excrement and charcoal, would be between five and six tons in weight. The Company contemplates the cleansing of the closet at long intervals, say once a year.

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The examination of the charcoal closets in Glasgow and the vicinity, proves, as was to be anticipated, that charcoal properly applied acts as a most effective deodorizer of excrement, and that this action, in receptacles kept dry, persists for an indefinite period. The assumption, however, that the mixed excrement and charcoal may, therefore, be safely stored for many months in the vicinity of or within the precincts of dwellings, appears to me to be at least premature. We know too little yet of the modes in which excrement acts in the production of disease to justify such assumption ; and we are not less ignorant of the action of charcoal upon the disease-producing qualities of excrement. Mr. Stanford's researches on the mode of action of charcoal on organic matter, suggests extreme caution in our conclusions on this subject. He believes, from his experiments, that the charcoal acts not as an oxidising agent, but simply as a drier.* The possible changes in a mixed mass of excrement and charcoal which may occur under various conditions of moisture and temperature are as yet wholly unknown.

But apart from these considerations there is the simpler question of the success which would probably be obtained among a mixed population in the ordinary use of charcoal as a privy deodoriser. The experience of Glasgow, even to the present time, shows, that there is no such surety of action to be obtained in this respect as Mr. Stanford and his Company contemplates, and that notwithstanding the great advantages accompanying the use of charcoal in deodorising excrement, the frequency of its removal from houses should be governed by other and wider considerations.

At the time of my visit to Glasgow, the Company had entered into a contract with the Corporation of Oldham to apply its process to the disposal of excrement in that borough. The preliminary arrangements for carrying out this contract had not been completed when this inquiry came to an end.

Slop Nuisance.

Slop Nuisance.

The abatement of nuisance from slops, including under that term the whole liquid refuse of a household, is part of the wider question of the disposal of sewage. The same principles apply in dealing with slops as with sewage, the two subjects merging the one into the other. Certain typical methods of slop disposal here described, came under observation during this inquiry.

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* "On the Action of Charcoal on Organic Nitrogen." *Journal of the Chemical Society*, January 1873.

Slop Nuisance.

1. In certain new cottages at Halton (Bucks), on the estate of Sir Anthony de Rothschild, the slops are conducted by a drain to a small water-tight receptacle in the garden, whence it is proposed that they shall be ladled from time to time for garden purposes. These cottages are provided with earth-closets, and each cottage has attached to it 40 poles of garden ground. It is calculated that the manure from the earth-closets and the slops may be all utilized in gardening this plot.

2. Another method of disposal is followed at the cottages of the Industrious Aid Society, Hereford. Here sub-irrigation is used to get rid of the slops. Each cottage has a garden-plot of a sixth of an acre, and in this plot sub-irrigation drains are laid for the slops, with small catch-pits at intervals. The slops, however, except when in large quantities, as the contents of a washing tub, penetrate but a very short distance into the drains. The porous loamy soil readily absorbs the liquid and no nuisance arises. Earth closets are attached to these cottages, as already described in the section on the Dry-Earth System.

3. A third method of disposing of liquid house refuse combines the two former methods, developing the first described into a system. This has been devised by the Rev. Henry Moule, M.A., vicar of Fordington, Dorsetshire. Mr. Moule, whose name is commonly associated solely with the dry-earth system of excrement disposal, has by no means limited his attention to that system alone. The dry-earth system, indeed, is perhaps most correctly described as a part of a more general scheme, which Mr. Moule is engaged in maturing for dealing with the whole refuse of a household. As part of this scheme I witnessed in a small plot of garden attached to his house the successful disposal and utilization of the whole of the liquid refuse of the household. This refuse flows to a catch-pit in the garden, which has an overflow into a sub-irrigation drain. The garden is cultivated by alternate cropping, the only manure applied to it being the fresh slops, which are ladled from the catch-pit and distributed to the garden daily. Luxuriant successive crops of garden vegetables are obtained in this manner, and Mr. Moule is of opinion, as the result of his experiments, that the liquid refuse of a family of from 17 to 20 persons can be thus profitably used on five or six perches of ground, as many as three or four crops being grown yearly. The following illustration of Mr. Moule's procedure may be given: On two perches of ground from which potatoes had been removed, drills were run, and after these had been saturated for two days with slops, brocoli was successfully transplanted to them in blazing sunshine. Then between the drills holes were made to the depth of 10 inches and prepared for subsequent transplantation of cabbages by filling them again and again with slops. Meanwhile on both sides of each row of holes a row of autumn carrots was sown.

So far as this inquiry was concerned the method described appeared to be a very feasible way of obviating nuisance from slops where garden ground and intelligent labour were available for its adoption.

4. A fourth method of disposal of slops, in which the difficulty of sub-irrigation by gravitation from the ordinary flow is overcome, has been invented by Mr. Rogers Field, C.E. Mr. Field is the owner of two cottages, at Shenfield, near Brentwood. When these cottages came into his possession they had much adjacent nuisance from their privies, and from the accumulation of slops in contiguous ditches. Mr. Field converted the privy pits into smaller watertight receptacles, with the object of their being used as earth-closets, but he failed, from inability to exercise frequent supervision, to induce the cottagers to use the earth. He succeeded, however, in preventing soakage

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of excremental matters from the privy-pit into the ground and in diminishing considerably their accumulation, and the nuisance therefrom. For some time he was puzzled in what manner to get rid of the slop nuisance, the irregularity and smallness of the flow foiling him in an attempt to direct it a sufficient distance along subsoil drains for any useful purpose and for the complete avoidance of nuisance. At length he devised a plan of accumulating the slops in a tank and discharging them at intervals rapidly by means of a siphon. The kind of tank first designed, and of which a pair have been in action at the cottages in question over six years, is shown in the accompanying drawing (Fig. 12). When this tank is full, a little additional slop thrown down

Slop Nuisance.

Fig. 12.

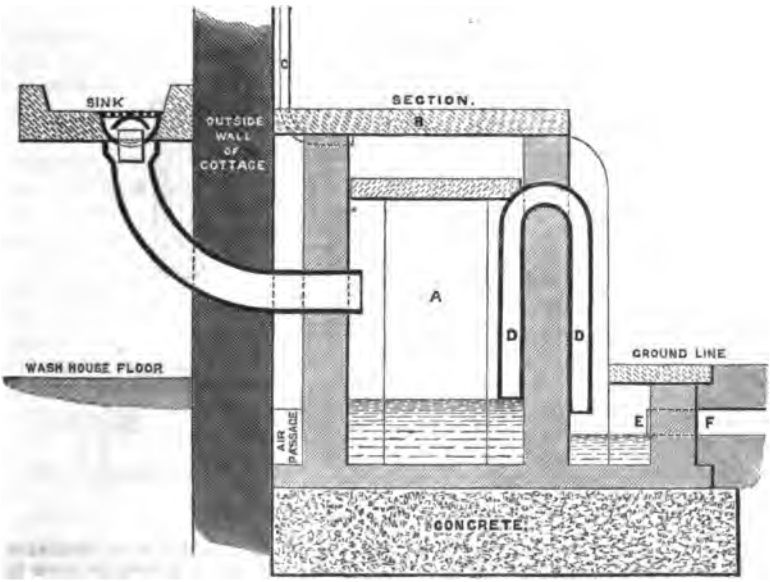

Fig. 12, A, a tank of about 33 gallons capacity, covered with moveable stone cover B, and provided with a ventilating pipe (C), which is carried up the outside of the cottage. The outlet from this tank consists of a siphon pipe (D), so arranged that when the liquid in the tank rises above the top of the siphon, it becomes charged, and empties the tank very rapidly. As soon as the sewage is lowered to the level of the bottom of the siphon (which is a short distance above the bottom of the tank, so as to leave a space for the deposit to be cleared out periodically), the siphon is thrown out of action, and allows the tank gradually to fill again with sewage. The siphon discharges through a small well (E) into a drain (F) leading to the sub-irrigation drains, which latter consist of common 2-in. agricultural drain-pipes laid about 12-in. below the surface of the cottage gardens.

the sink starts the siphon in action, and the contents are emptied with sufficient rapidity and force to carry them a considerable distance along the drains attached to the tank.

The action of this tank, as far as the abatement of slop nuisance is concerned, has been complete, and except an occasional cleansing at somewhat long intervals, and an examination of the drains with which it is connected in order to obviate any stoppage, its operation has involved no trouble. But sundry defects in the action and arrangement of the tank were brought to light by experience. The point of entrance of the sink drain was undesirable, the slops backing up in the drain as the tank filled, and the water from the bell-trap of the sink being

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occasionally emptied by the suction action of the siphon. It was objectionable also that urine from the bed-chamber and in chamber slops could not be poured into the tank except from the sink. Again, the quantity of water required to start the siphon when the tank became full was too large, and it happened that smaller quantities thrown down the sink at this time would simply cause an overflow through the siphon, the slops dribbling away until their level in the tank fell to the level of the siphon's bend. These defects have been remedied by Mr. Field, and the flush-tank as now designed and fabricated in iron

Fig. 13.

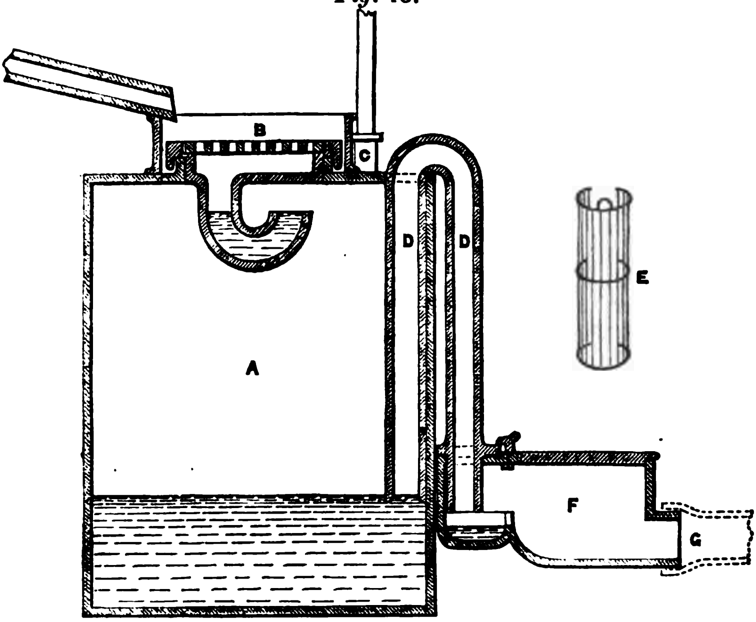


Fig. 13. This apparatus consists of a cylindrical watertight iron or stoneware tank (A). This tank has a trapped inlet (B), which also forms a movable cover to give access to the inside of the tank, and a socket (C) for a ventilating pipe. The outlet consists of a siphon (D), so arranged that no discharge takes place till the tank is completely filled with liquid, when the siphon is brought into action and the contents are immediately discharged. The inner end of the siphon is protected by a wire strainer (E), and the outer end enters a discharging trough (F), which is made to turn round so that its mouth may be directed as required to connect the tank with the line of outlet pipes (G). This trough has a cover which can be removed to give access for cleaning.

or stoneware, appears to be perfect in action. A drawing of this tank is given in Fig. 13.

It will be observed in this figure that the sink drain opens outside the tank above a trapped inlet; and that the long limb of the siphon terminates in a small trough. This trough is so arranged that any trickle of slops along the siphon quickly closes the outlet; and continuation of the trickle after this closure, from air contained in the siphon being carried along with the liquid, exhausts the siphon sufficiently to cause it to be brought into action by the preponderating atmospheric pressure upon the surface of the liquid in the tank. By this ingenious arrangement a much less quantity of liquid thrown down the sink will start this siphon in action than in the tank first designed, and abortive flow from the tank is obviated.

The flush-tank is made of different sizes, varying in capacity from 16 to 30 gallons, exclusive of space for deposit. When in continuous use

the interior should be cleansed and the deposit (a useful manure) removed every month.

Slop Nuisance.

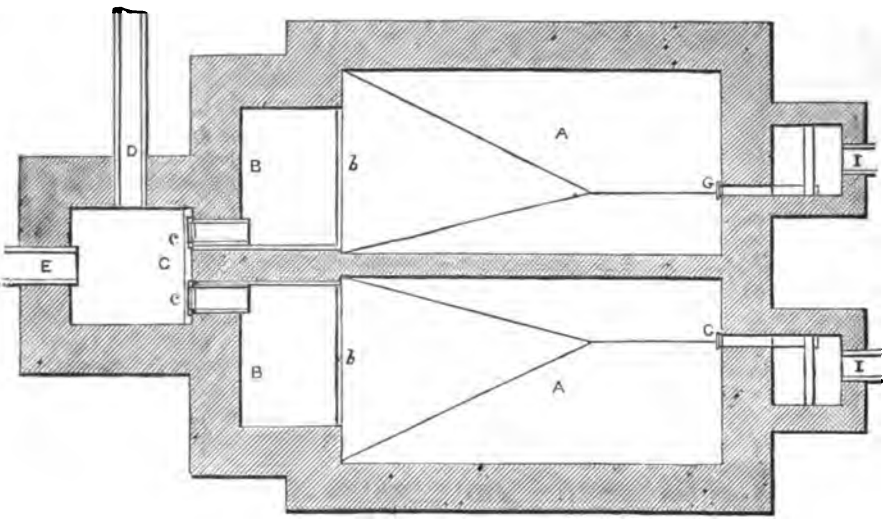
I subjoin a plan of the cottages at Shenfield and the arrangements of their drains. (*Plate* XXXV.) The sub-irrigation drains, formed of 2-inch agricultural pipes, are laid, at a depth of about 12 inches, upon a bed formed of larger agricultural pipes divided longitudinally in half. If this bed be properly arranged by a skilful workman in the first instance, subsequent examinations and replacing of the drain for the purpose of removing stoppages (which should be done every twelve months) may be effected by an ordinary labourer. The sub-irrigation drains are connected with the flush-tank by a longer or shorter portion of water-tight drain, according to the position of the irrigated land with reference to the house. In cases where it is requisite to prepare the soil first for irrigation by subsoil drainage it is necessary in laying the drains for sub-irrigation with slops so to place them that their contents may not pass unaltered into the land drains. It is also necessary, for the same reasons, to give regard to their relation to wells used for drinking purposes or cooking.

Each of the gardens attached to the cottages at Shenfield measures 7 perches; but Mr. Field is of opinion, from the experience of the flush-tank at these cottages, that four perches would be sufficient ground for the effective disposal and utilization by sub-irrigation of the slops from an ordinary cottage.

The foregoing invention for separate houses has been further developed so as to meet the general wants of a community by Mr. J. Bailey Denton, C.E., in conjunction with Mr. Field. The same difficulties have been experienced in dealing with and utilizing readily, economically, and inoffensively, the liquid house refuse of villages and towns, as with that of separate houses, and from the same causes, the ordinary insignificance, and occasional irregularities of flow. To meet these difficulties Messrs. Bailey Denton and Field have designed a tank termed by them "*The Automatic Sewage Meter*," which is constructed on the same principles as Mr. Field's self-acting flush-tank. This "meter" provides for the accumulation of the liquid refuse and for its automatic discharge, at definite intervals, in quantities admitting of distribution over land by gravitation, for purposes of irrigation. A meter of this kind has been in use about three years in the hamlet of Eastwick, near Leatherhead, in Surrey, and its operation, particularly as part of the sanitary arrangements of the village, may there be studied very usefully.

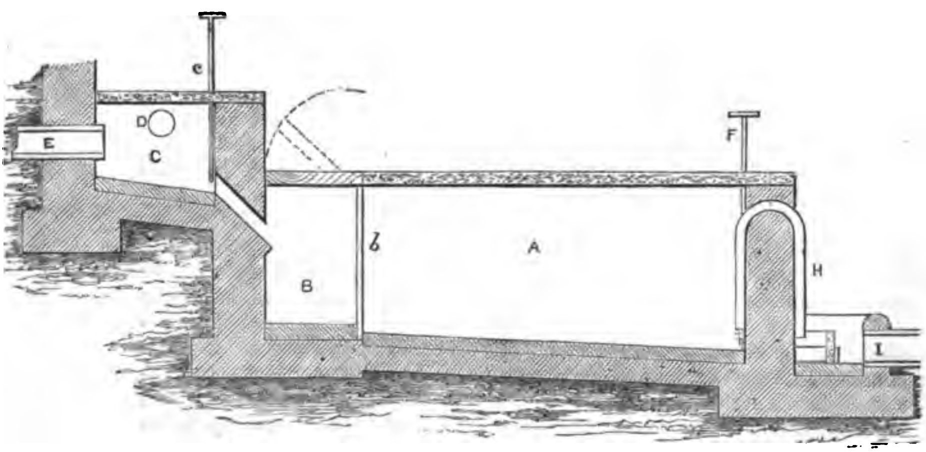
Eastwick is a hamlet of 13 houses, including the mansion of the proprietor and the farm homestead; and it has a population of about 145. In devising a system of excrement and slop disposal for the place, any general plan of water sewerage had to be set aside, the water supply derived from wells being variable in quantity, and at no time too abundant for ordinary domestic use, irrespective of waterclosets. The common privy was retained for the cottages, but the privy-pit was converted into a water-tight receptacle beneath the floor of the closet, and the cottagers were instructed to throw into it above the excrement the refuse ashes, and to remove the contents of the pit monthly for use in their gardens. Four waterclosets exist and five earth closets for the use of the mansion and its precincts; and one watercloset and three earth-closets for the use of the farm homestead. To provide for the liquid house refuse of the hamlet, and for the drainage of the farm buildings, the scheme of sewerage was carried out by Mr. Bailey Denton which is shown in the accompanying plan (*Plate* XXXVI.), and which has an outlet in a meter tank, of which the plan and section are given in the followir figures (Figs. 14 and 15).

Fig. 14.



THE AUTOMATIC SEWAGE METER-TANK (PLAN).

Fig. 15.



THE AUTOMATIC SEWAGE METER-TANK (SECTION).

Figs. 14 and 15, A, the meter-tank ; B, the straining chamber ; *b*, the strainer ; C, sluice chamber, with sluices, *c*, governing communications with straining chambers ; D, overflow ; E, sewer ; F, sluice for draining off sediment through the pipe G ; H, siphon ; I, delivering pipe.

App. No. 7.

On Excrement Nuisances, by Mr. J. Netten Radcliffe.

Slop Nuisance.

The tank is in two compartments, to admit of cleansing without entire disuse. It has a capacity of 500 gallons, and it fills and discharges in ordinary dry weather three times in two days. The several discharges are directed successively on different portions of a plot of ground prepared for the purpose, and which measuring 3 roods 3 perches serves ordinarily for the effective and profitable utilization of the whole liquid refuse of the several cottages, the mansion, and the farmstead. The drainage of the latter includes the flow from cattle sheds and stables, in which from 15 to 20 animals are always present, and about 30 head of horned cattle, and 30 horses at intervals. The drainage of a large piggery also passes to the tanks.

Luxuriant crops have been grown upon the irrigated land, last year's crop consisting of the thousand-headed cabbage. Of this crop, Mr. Hutchinson, the steward of the estate, says:—"Besides thriving so well "upon the sewage, it is an excellent food for milk cows, being less "strong in taste than the drumhead and not having any but a good "effect upon the milk. The thousandhead can also be used as human "food. I estimate the value of the crops obtained at 25*l.* per annum, "or at the rate of 32*l.* 10*s.* per acre; and the outlay in attendance "upon the land and the regulator ("meter") I put down at 7*l.* 16*s.*"

Mr. Bailey Denton, to whom I am also indebted for the plan, has courteously sent me the following statement of the cost of the works above described, including the "meter" and the preparation of the land, and he remarks upon this statement that:—"the yearly return, "after deducting the cost of attendance upon the sewaged land and "regulator cannot be less than 17*l.* per annum, so that already a return "of about 5 per cent., on the outlay is gained, while there is every "prospect of increasing that return as the quantity of sewage dealt "with becomes greater and its treatment becomes better understood."

Eastwick Sewerage.

	£	s.	d.
To payment for labour - - - -	179	4	0
„ „ pipes - - - -	103	7	2
„ „ stone, lime, cement and sand -	12	14	0
„ „ iron and lead work - -	20	5	1
„ „ carriage of materials - -	1	9	1
Travelling and incidental expenses - -	3	12	0
	320	11	4

In regard to abatement of slop nuisance, and I may add also largely of farm nuisance, among a rural community, the arrangements at Eastwick are the most complete and satisfactory I have yet seen. Notwithstanding the contiguity of the irrigated land to the mansion, no nuisance is experienced from it, whereas previous to the present arrangements, when the slops of the mansion and cottages found their way into neighbouring ditches and decomposed there, considerable nuisance had existed. With some structural alterations in the privies (the principles of which are stated in their proper place in this report) and such needed supervision as will now be obtained from the Sanitary Authority appointed under the Public Health Act, 1872, the arrangements at Eastwick may be regarded as a pattern to be followed by villages and small towns similarly circumstanced.

App. No. 7.

On Excrement Nuisances, by Mr. J. Netten Radcliffe.

Slop Nuisance.

From what has already been said it may be inferred that the "Automatic Sewage Meter" admits of wide application in removing the difficulties which often beset the disposal of the sewage of communities larger than Eastwick. It simplifies the whole question of dealing with the sewage of small towns, villages, isolated institutions, and mansions, while securing the most efficient application of the sewage to land, both for purification and utilization, with the least expenditure of labour.

5. In my observations under the head of Gloucester, I have referred to certain experiments of Dr. Francis T. Bond, on the depuration of slops by a combined process of straining, chemical precipitation, and filtration. These experiments should be had in mind as at least giving promise of successful dealing with slop-nuisance under conditions to which the simpler methods already described might not be applicable.

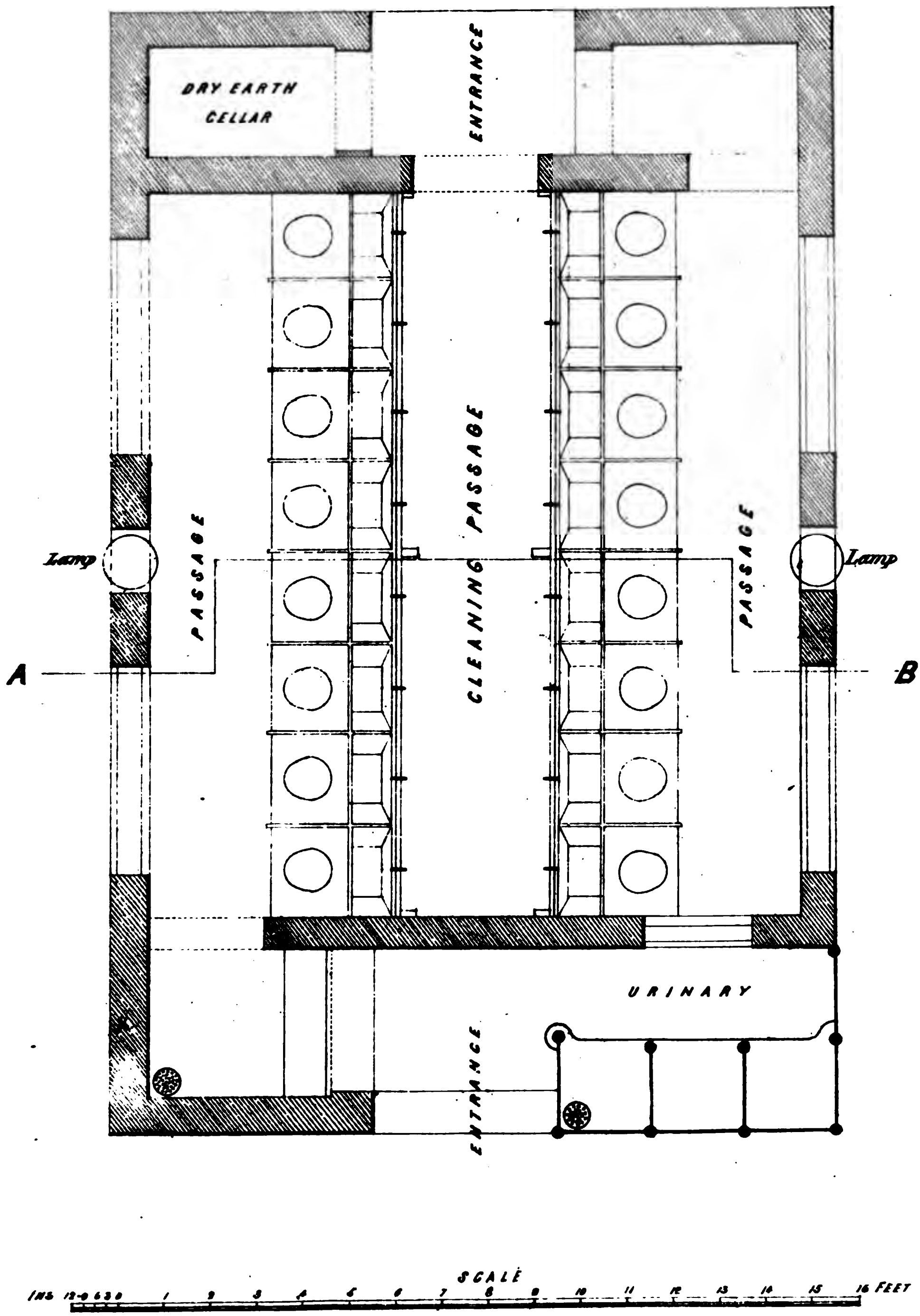
The various methods of slop-disposal which have been described meet the greater number of the conditions under which slop-nuisance is apt to occur. With the exception of Dr. Bond's method, all dispose of the slops by distributing them to the soil either upon or beneath the surface, or in both ways, intermittently—in other words, by intermittent irrigation.

LONDON:
Printed by George E. Eyre and William Spottiswoode,
Printers to the Queen's most Excellent Majesty.
For Her Majesty's Stationery Office.

EDINBURGH CORPORATION.

No. 1

Dry Earth Closet in Burnet's Close.
EDINBURGH.



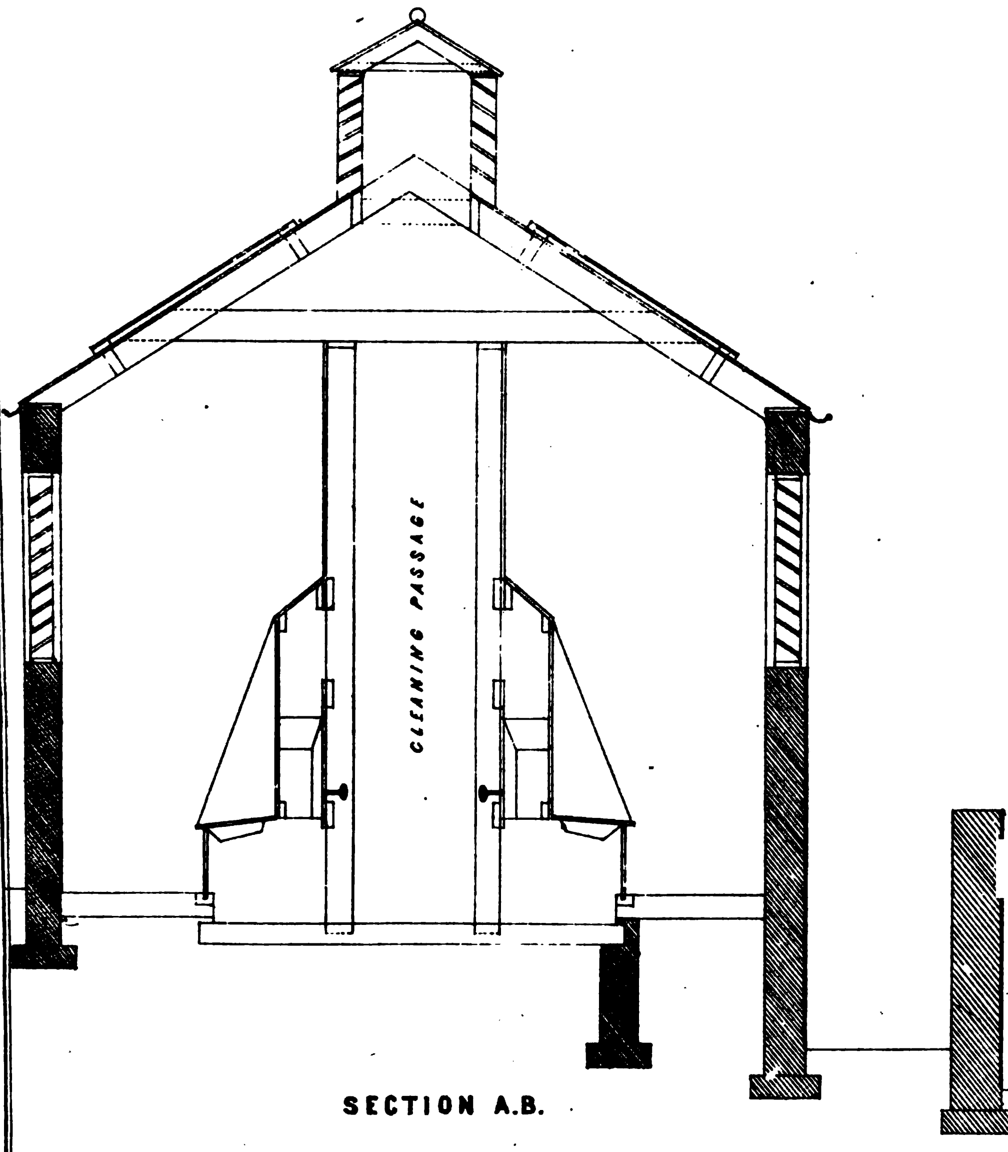
BURGH ENGINEER'S OFFICE,
Edinburgh, 8th Sept. 1874.

Dangerfield Lith. London

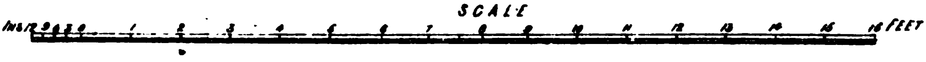
No. 2.

EDINBURGH CORPORATION.

Dry Earth Closet in Burnet's Close,
EDINBURGH.



SECTION A.B.



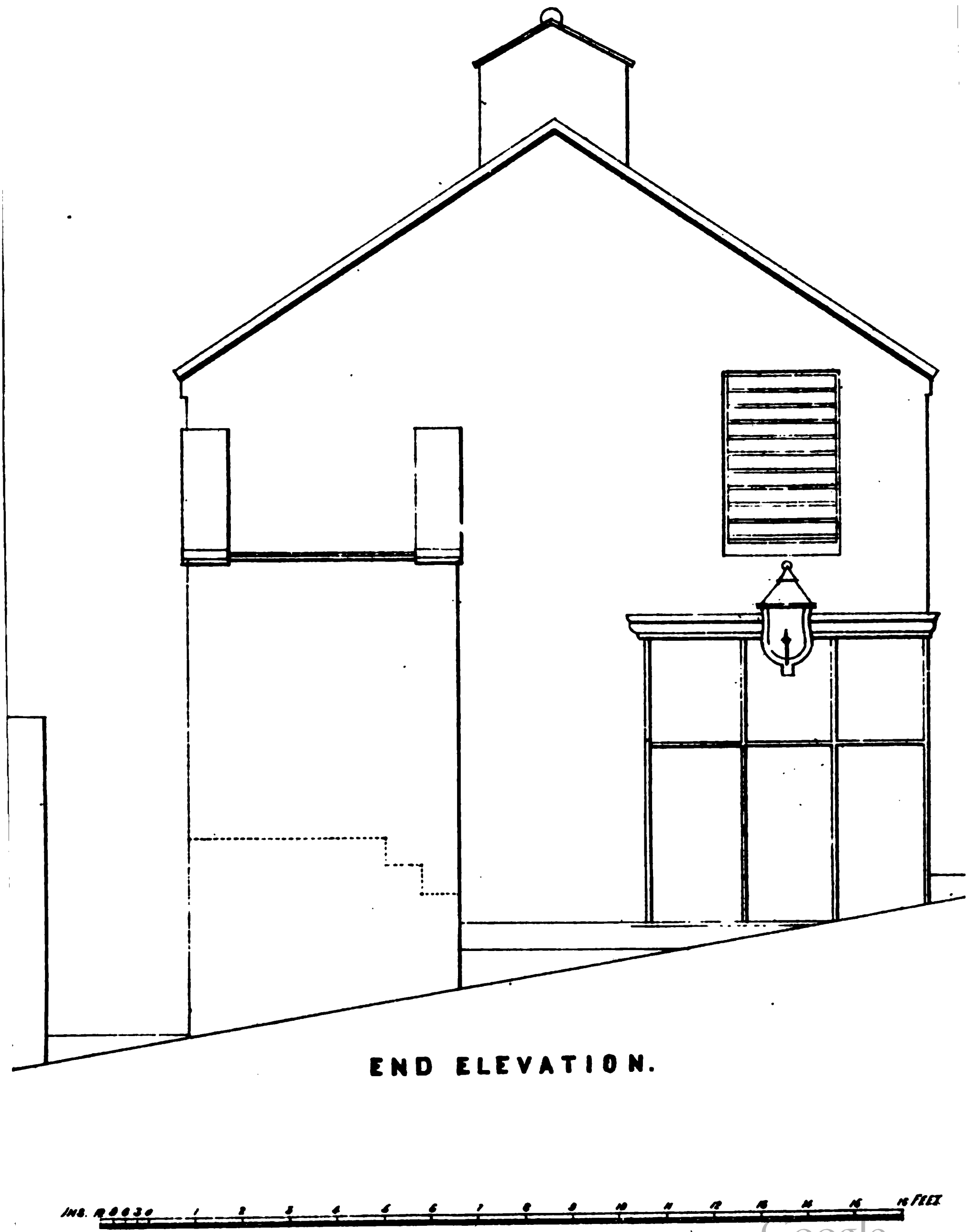
BURGH ENGINEER'S OFFICE,
Edinburgh. 8th Sept. 1874

No. 3

EDINBURGH CORPORATION.

Dry Earth Closet in Burnet's Close,

EDINBURGH.



END ELEVATION.

BURGH ENGINEER'S OFFICE,
Edinburgh. 8th Sept. 1874.

EDINBURGH CORPORATION.

No. 4.

Dry Earth Closet in Burnet's Close,
EDINBURGH.

END ELEVATION.

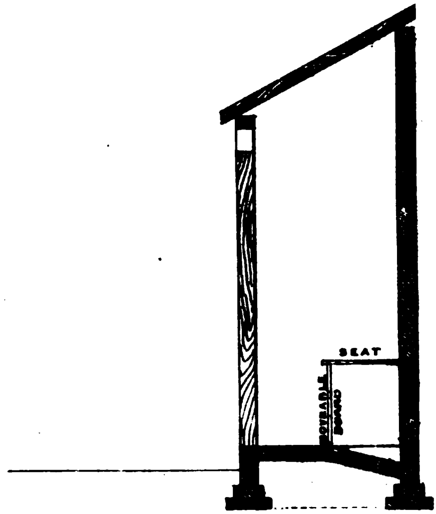
SCALE

INS 12 9 6 3 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 FEET.

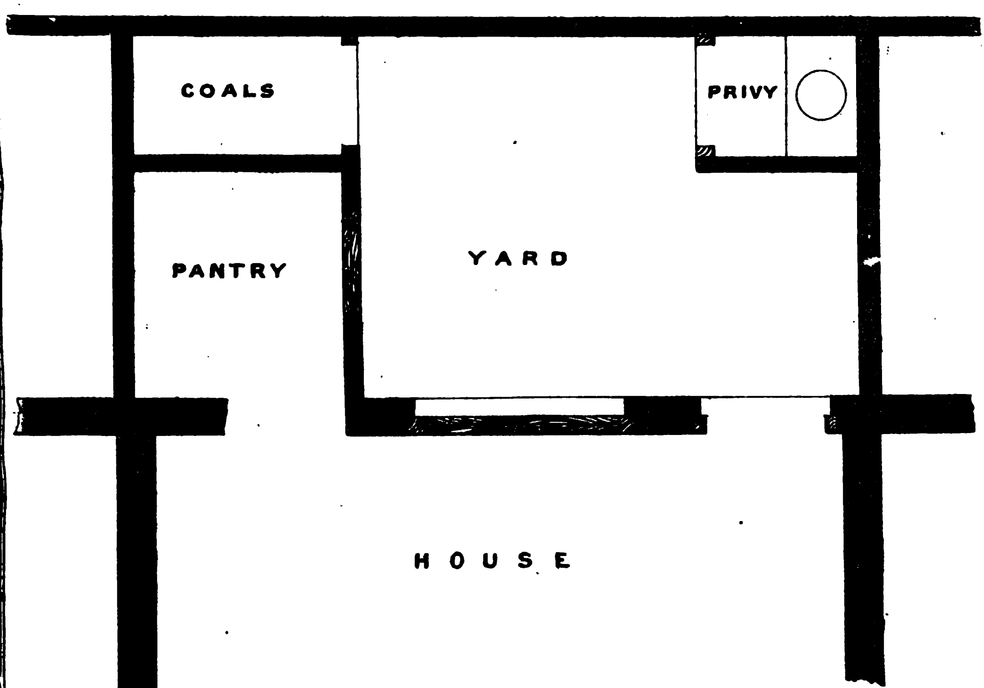
BURGH ENGINEER'S OFFICE.
Edinburgh 8th Sept. 1874.

HULL.

Approved Construction and Arrangement of Ordinary Privies with Plan showing the Smallest Yard Space allowed in New Houses.



SECTION OF PRIVY



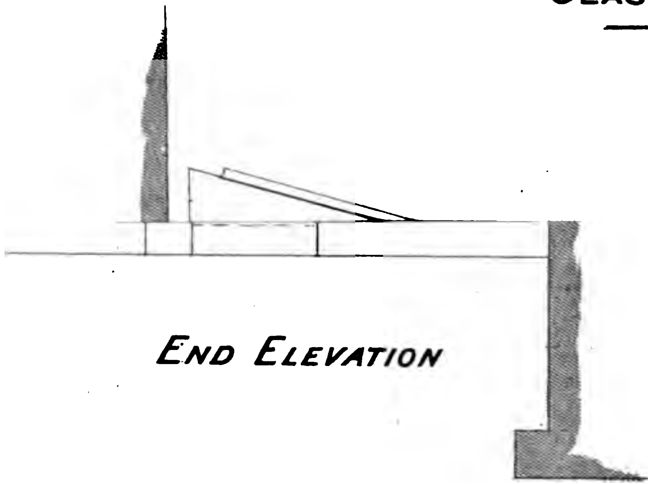
Scale 4 Feet to an Inch.

Dangerfield, Lith. London.

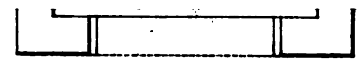
No. 1.

PLAN OF PRIVY
AT No. 24 WILSON St.

GLASGOW CORPORATION.



END ELEVATION



PLAN

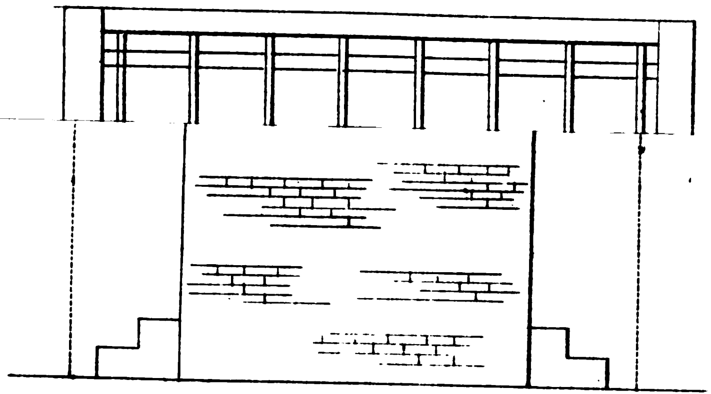
SANITARY CHAMBERS.
No. 1, Montrose Street,
GLASGOW.

Dangerfield, Lith. 22, Bedford St. Covent Garden.

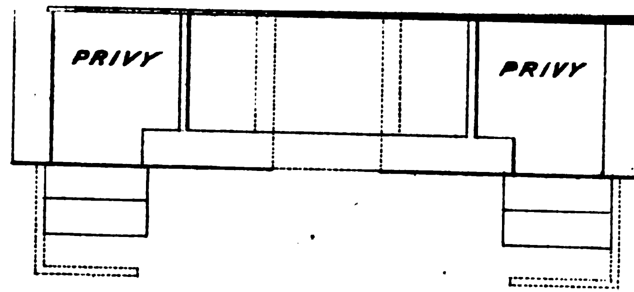
No 2.

PLAN OF PRIVY
AT 25 AND 33 TRONGATE.

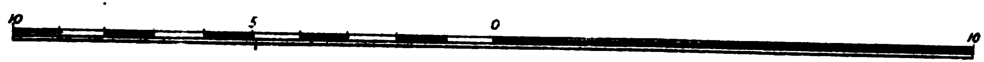
GLASGOW CORPORATION.



END ELEVATION



PLAN

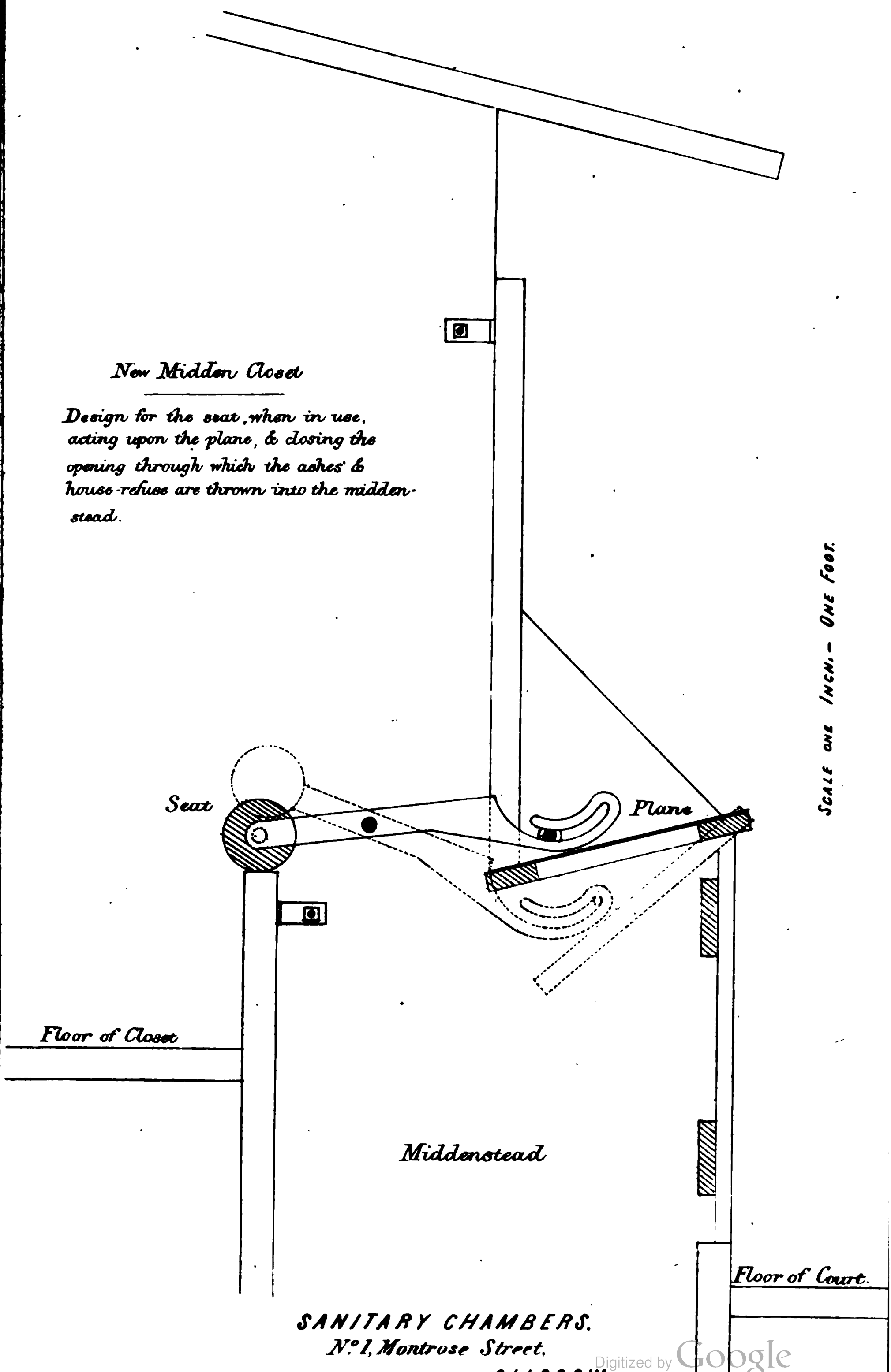


SANITARY. CHAMBERS.
No 1 Montrose Street.
GLASGOW.

GLASGOW CORPORATION

New Midden Closet

Design for the seat, when in use, acting upon the plane, & closing the opening through which the ashes & house-refuse are thrown into the midden-stead.

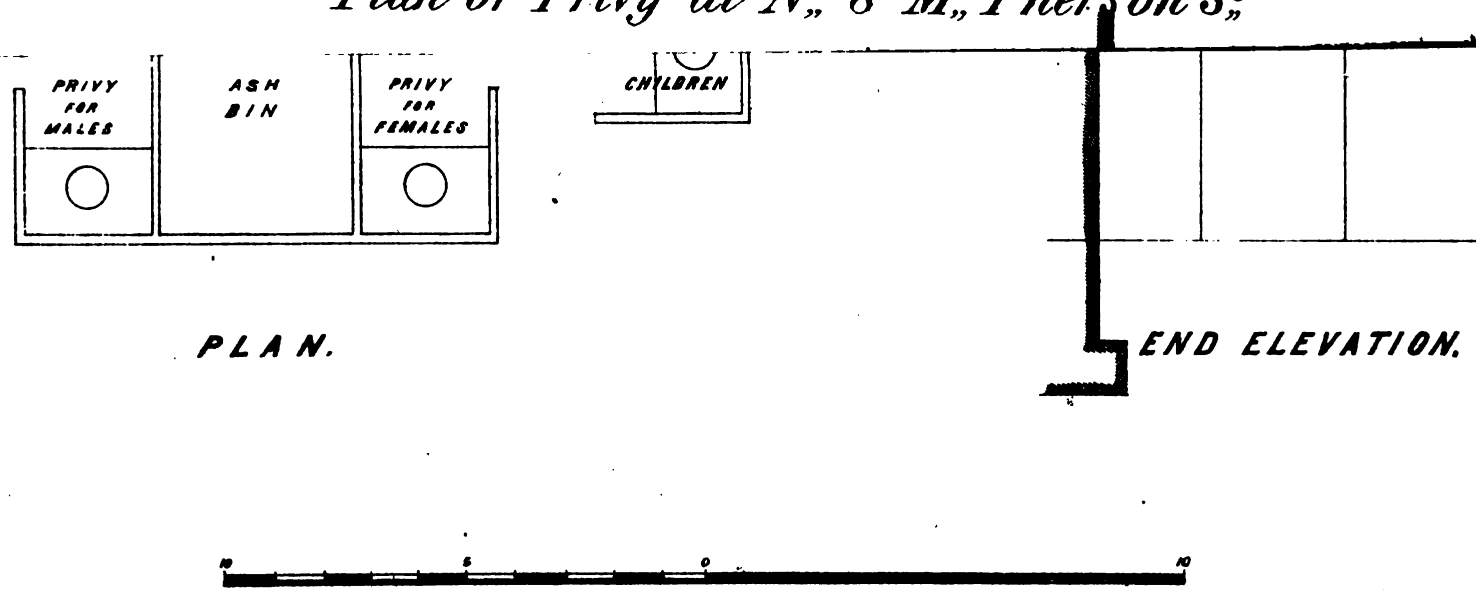


SANITARY CHAMBERS.
No 1, Montrose Street.
GLASGOW.

Dangerfield, Lith. London

GLASGOW CORPORATION.

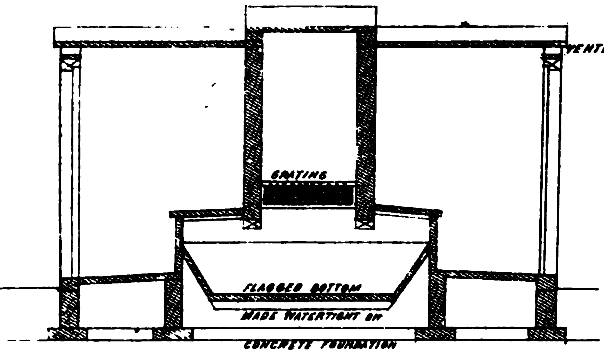
Plan of Privy at No. 8 McPherson St.



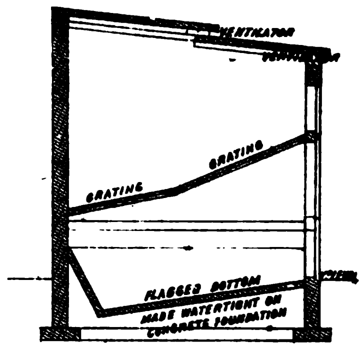
SANITARY CHAMBERS,
No. 1, Montrose Street,
GLASGOW.

BRADFORD CORPORATION.

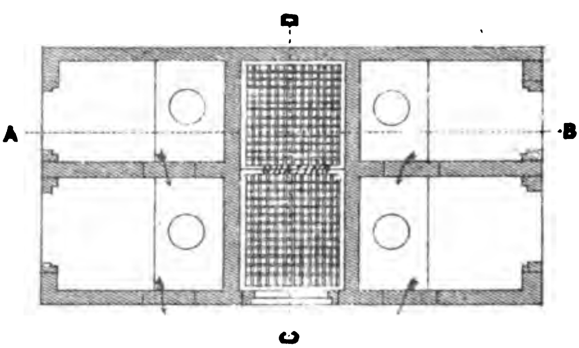
Approved plan of Privies and Ashpit.



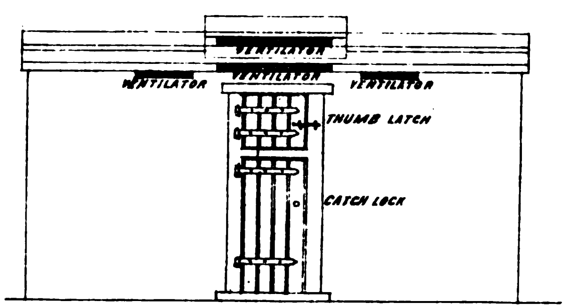
SECTION ON LINE A.B.



SECTION ON LINE C.D.



PLAN

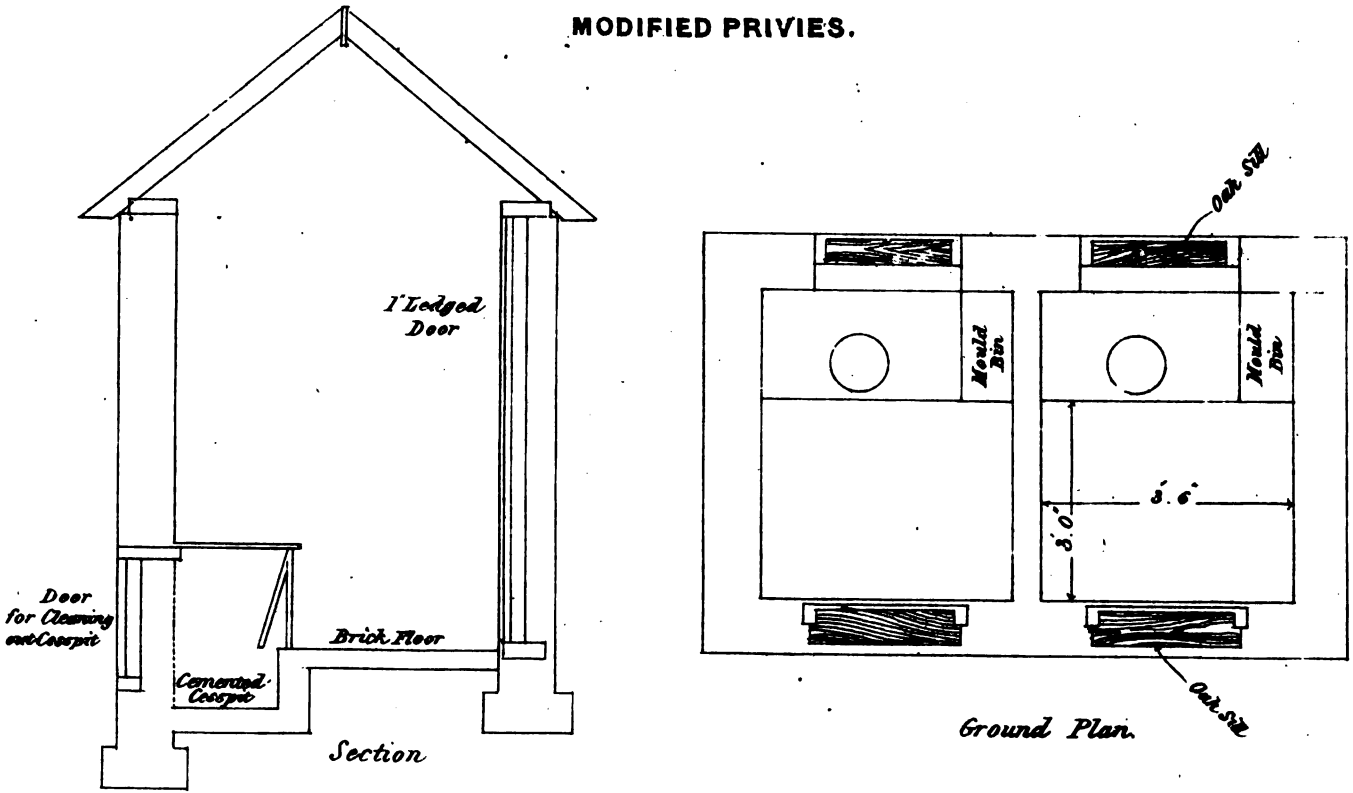


ELEVATION.

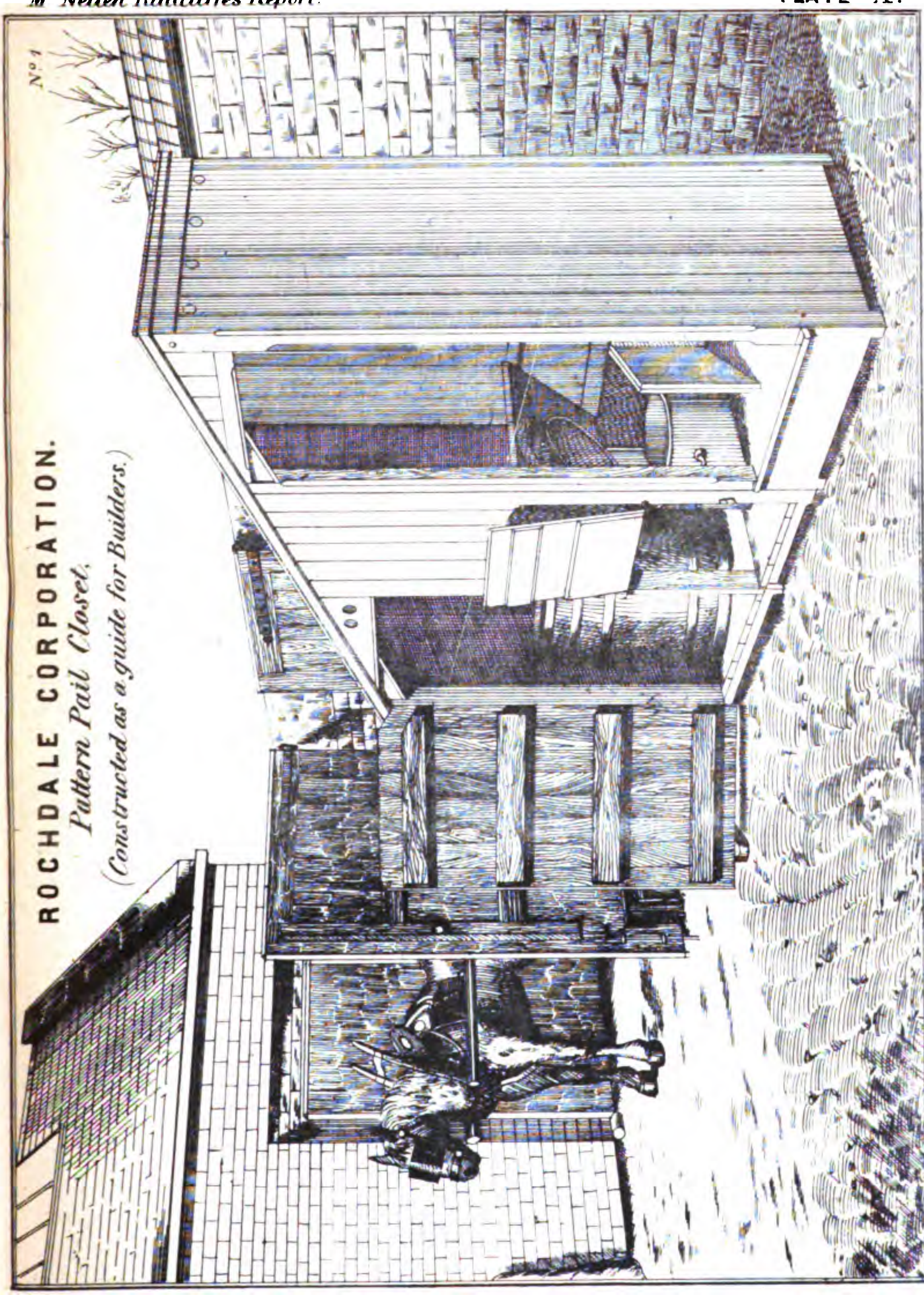
Scale, 1 Inch = 5 1/3 Feet.

TRING URBAN SANITARY AUTHORITY.

MODIFIED PRIVIES.

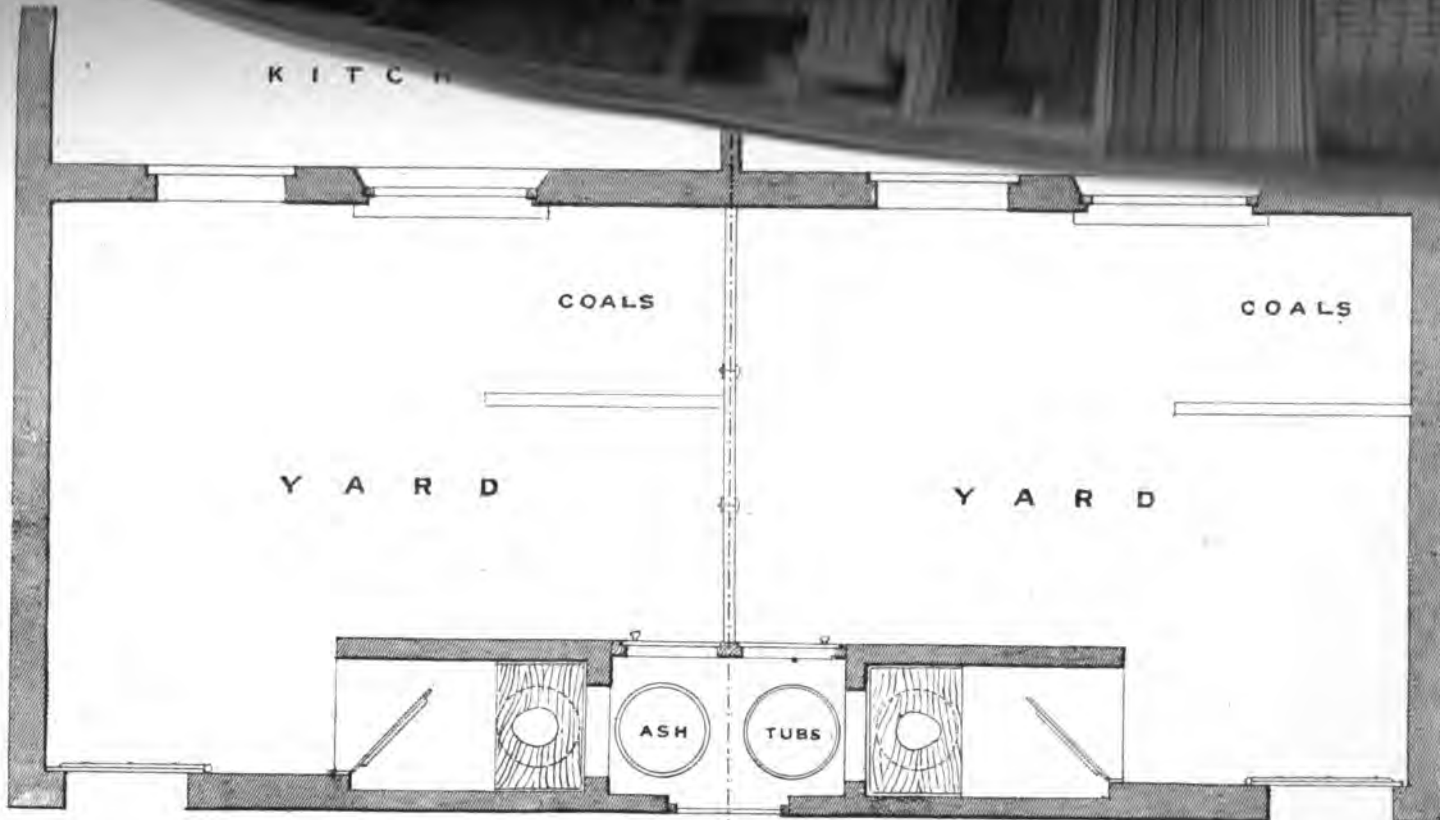


Scale 2 feet to 3/4 inch



ROCHDALE CORPORATION.
Pattern Pail Closet,
(Constructed as a guide for Builders.)

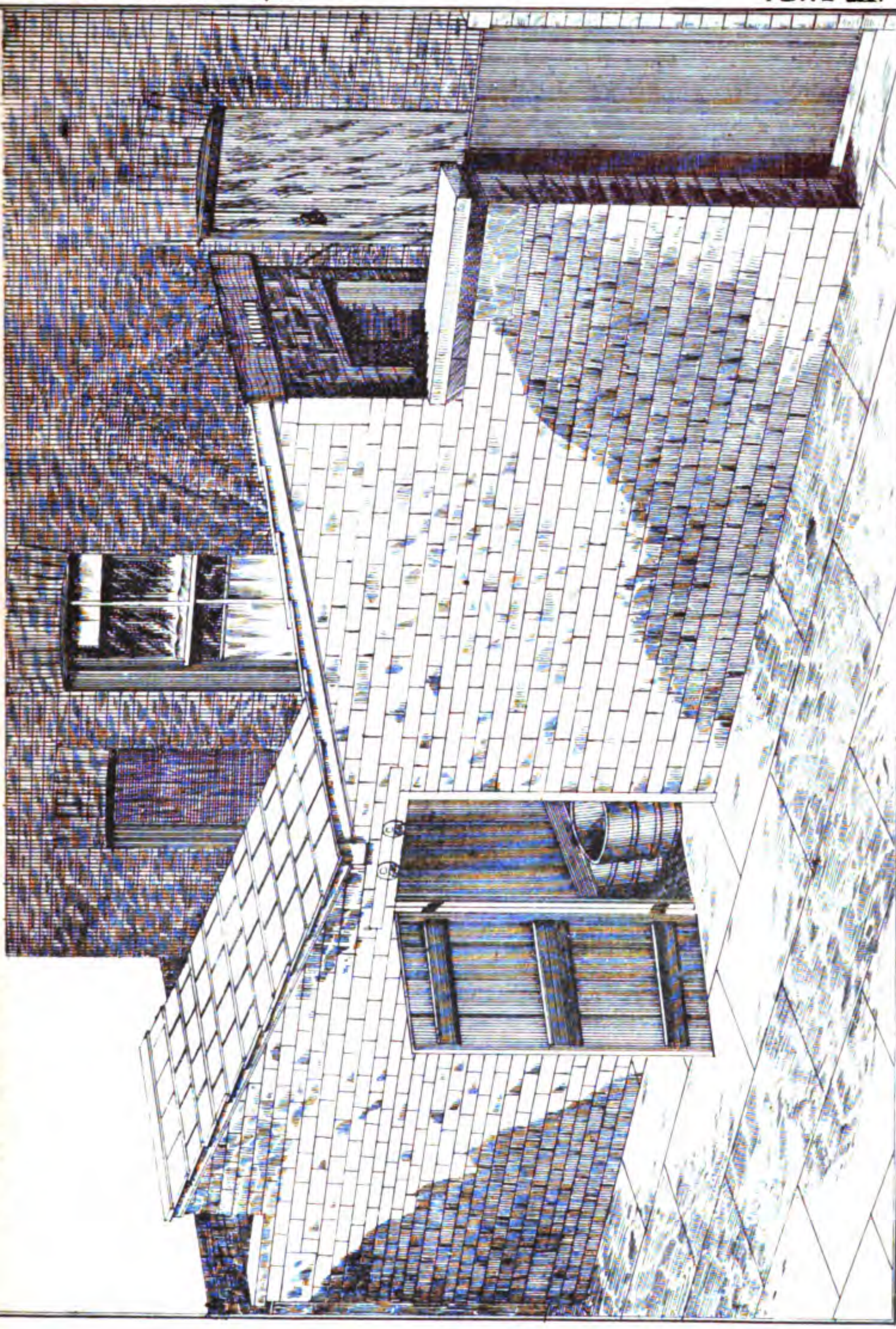
PLATE XII.



Scale 4 Ft.=1 Inch.

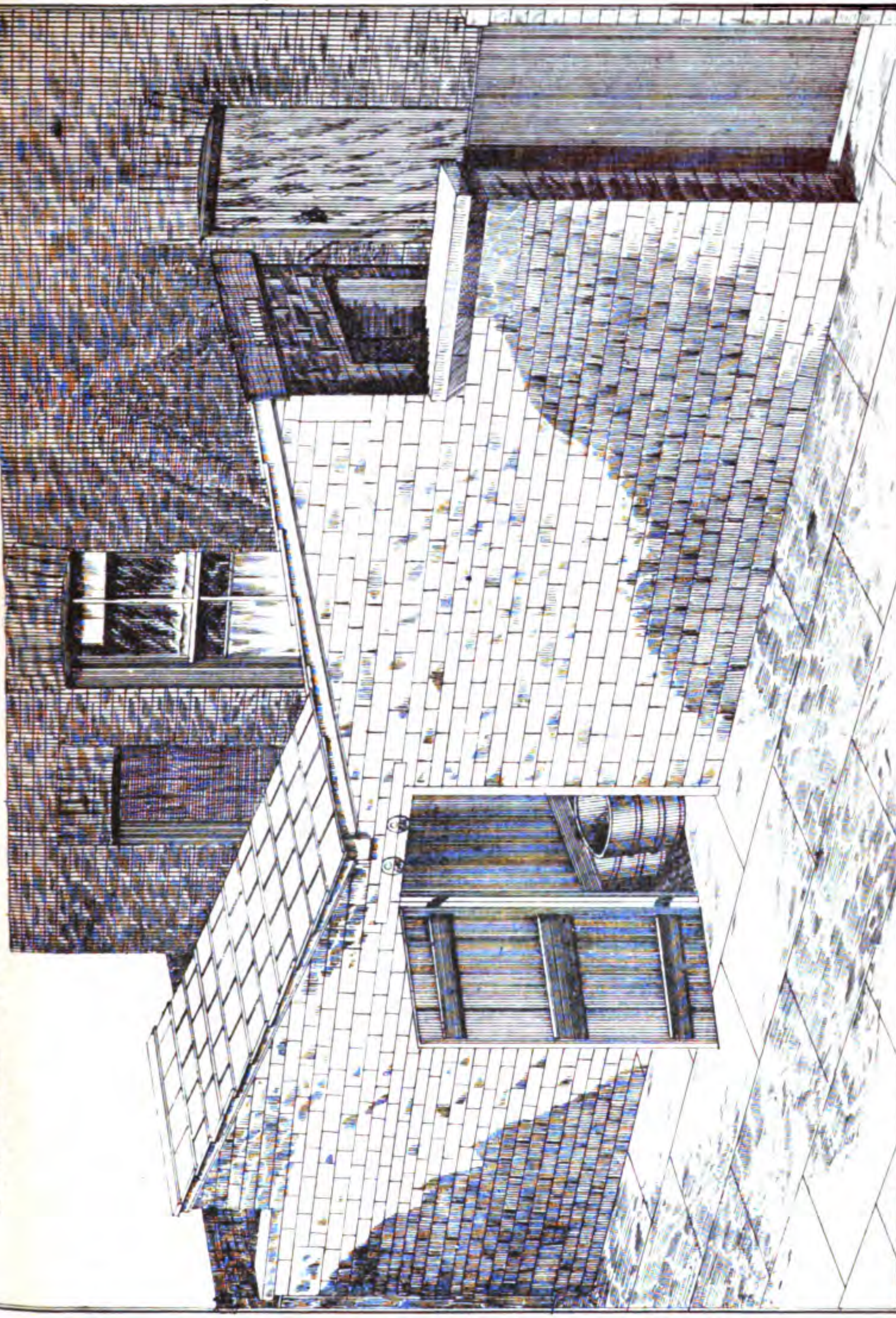
Dangerfield Lith London

ROCHDALE CORPORATION. *Pail Closets as Erected on New Property.* No. 2.



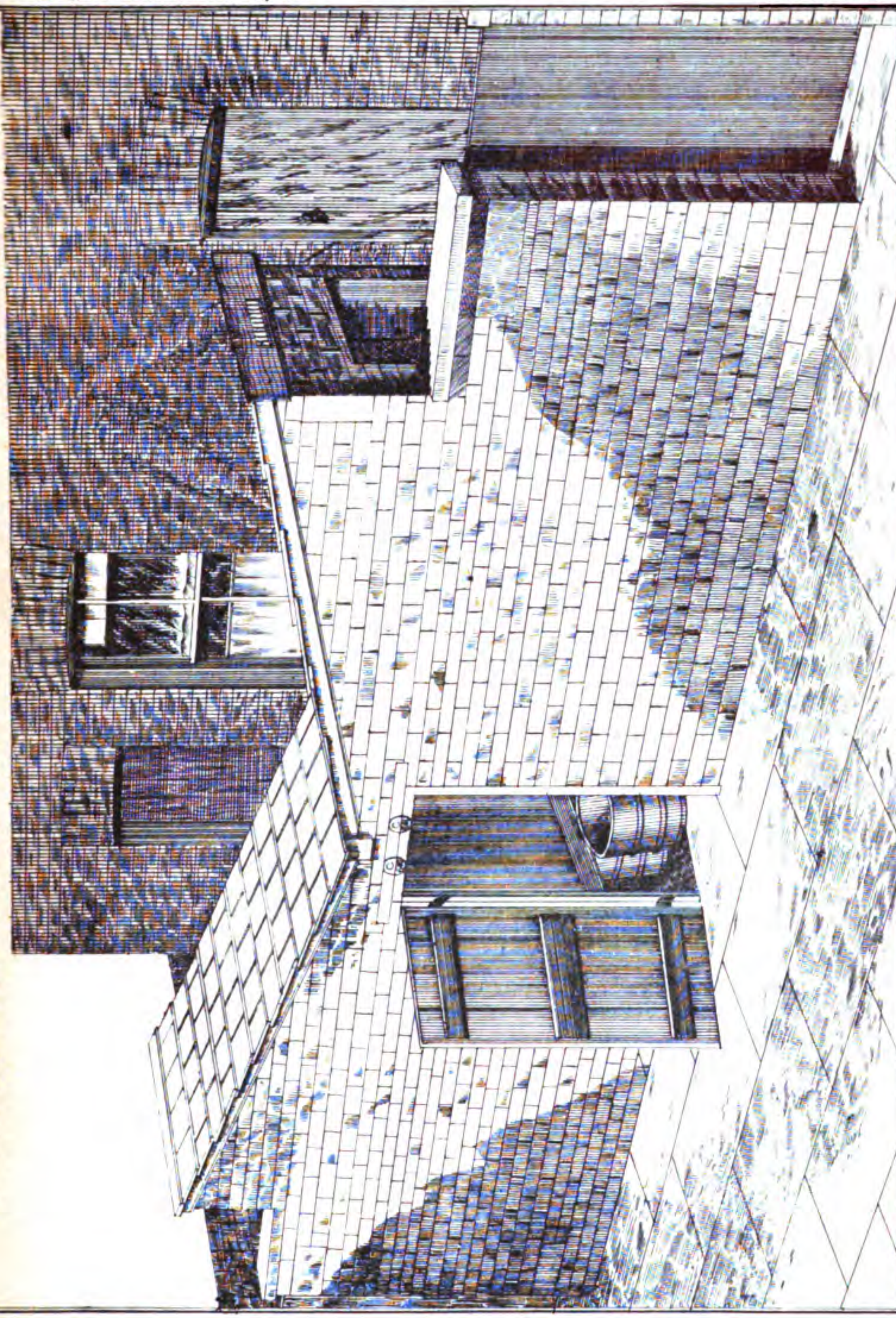
Dangerfield Lith. London

ROCHDALE CORPORATION. *Pail Closets as Erected on New Property.*



Dangerfield Lith London

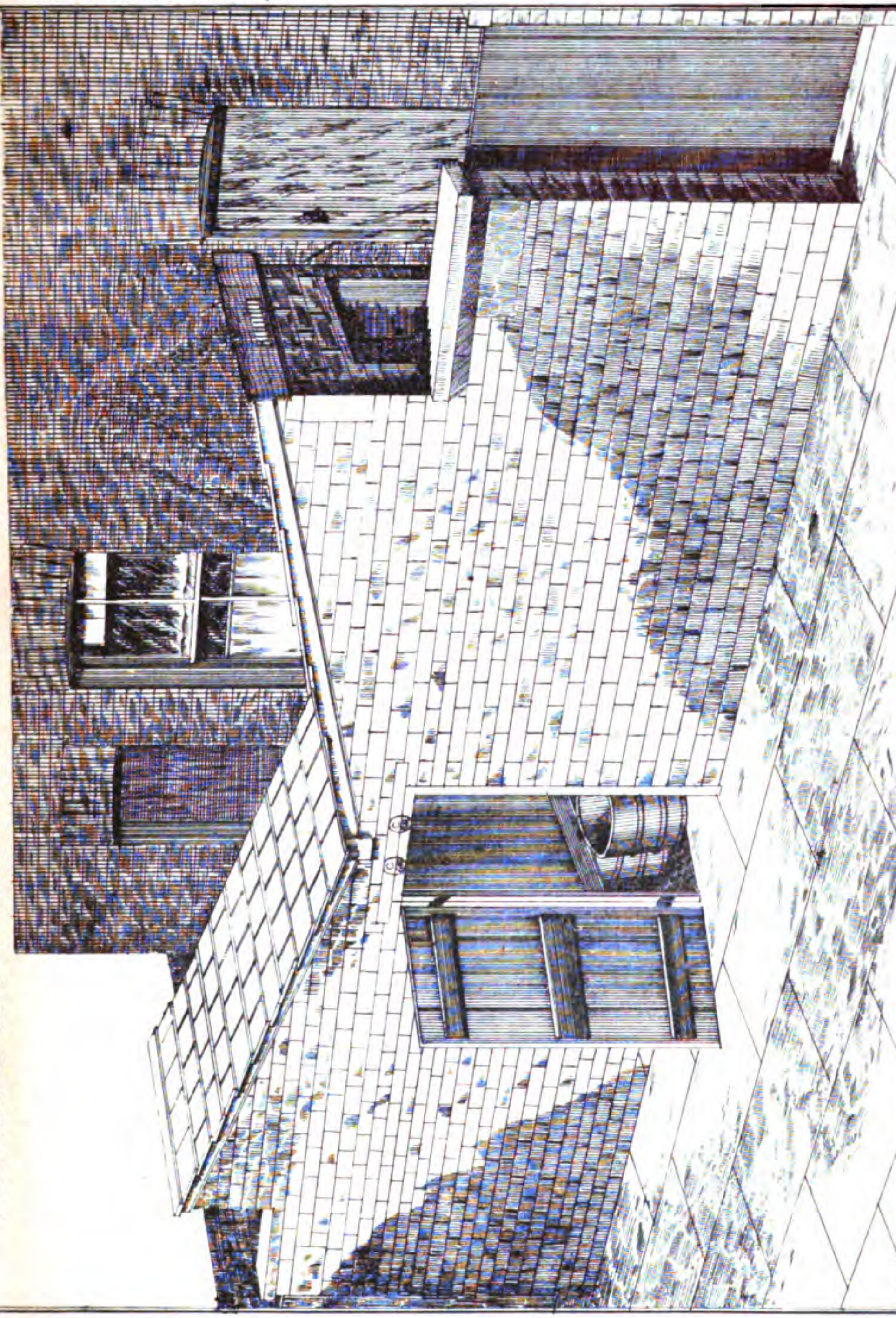
ROCHDALE CORPORATION. *Pail Closets as Erected on New Property.* No 2.



Dangerfield Lith. London

ROCHDALE CORPORATION. *Pail Closets as Erected on New Property.*

No. 2.

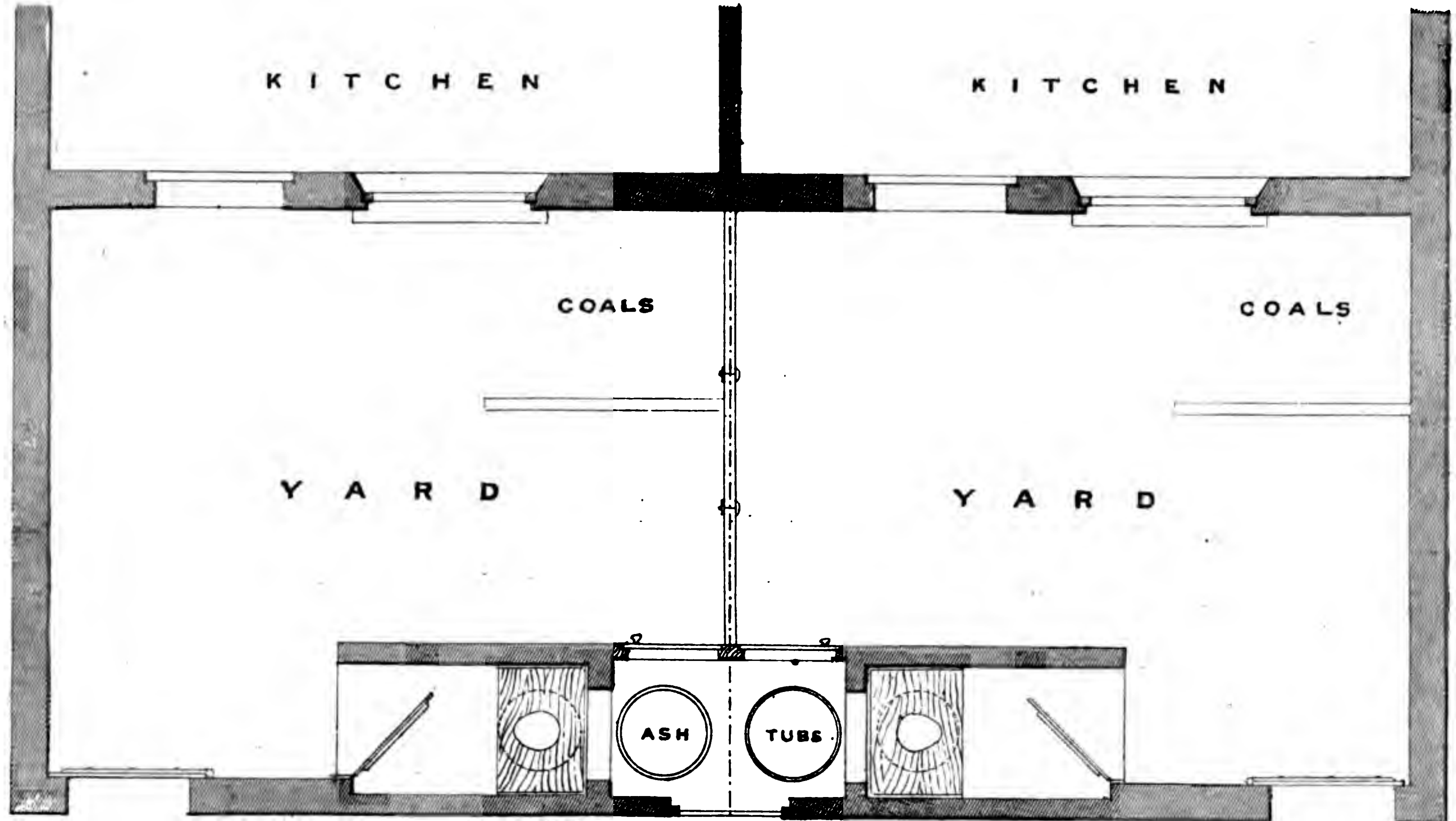


Dangerfield Lith London

No 3.

(3) ROCHDALE CORPORATION.

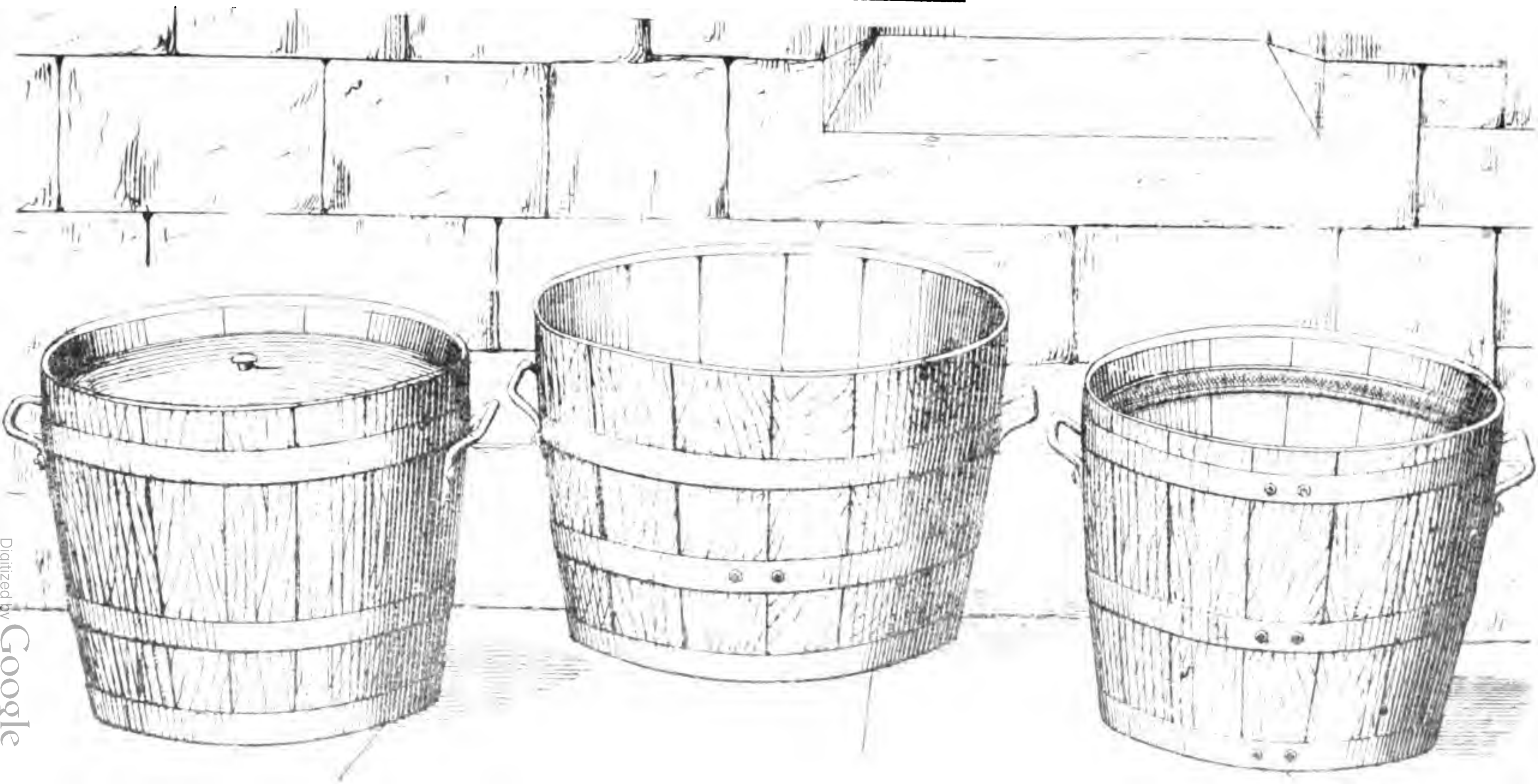
GROUND PLAN OF BACK PREMISES OF TWO DWELLING HOUSES SHOWING ARRANGEMENT. OF PRIVIES AND ASHPLACE.



Scale 4 Ft.=1 Inch.

Danielfield Lith London

ROCHDALE CORPORATION.



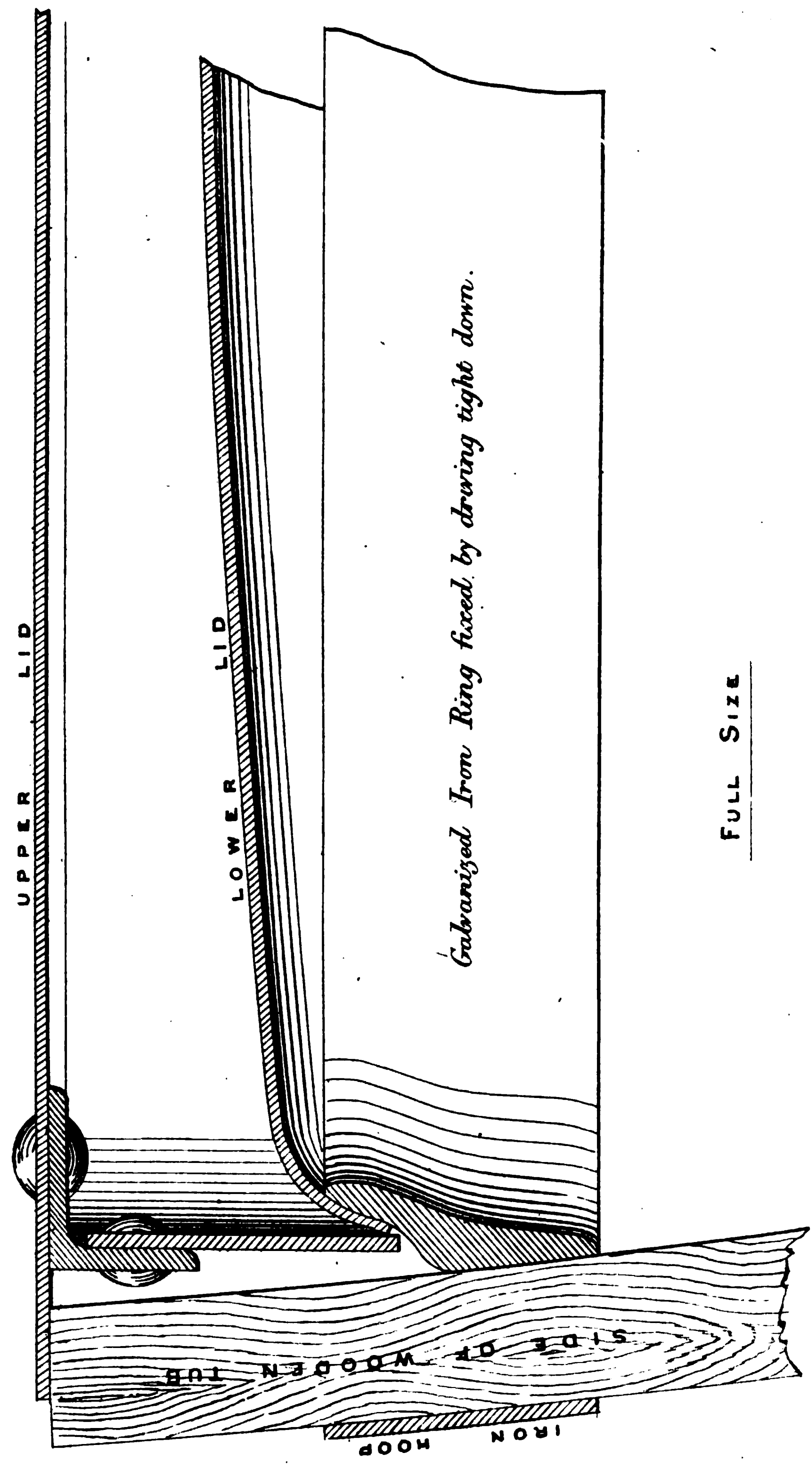
Excrement Pail with lid on full, to return to Works

Ash Tub Empty

Excrement Pail empty ready for use

No. 5.

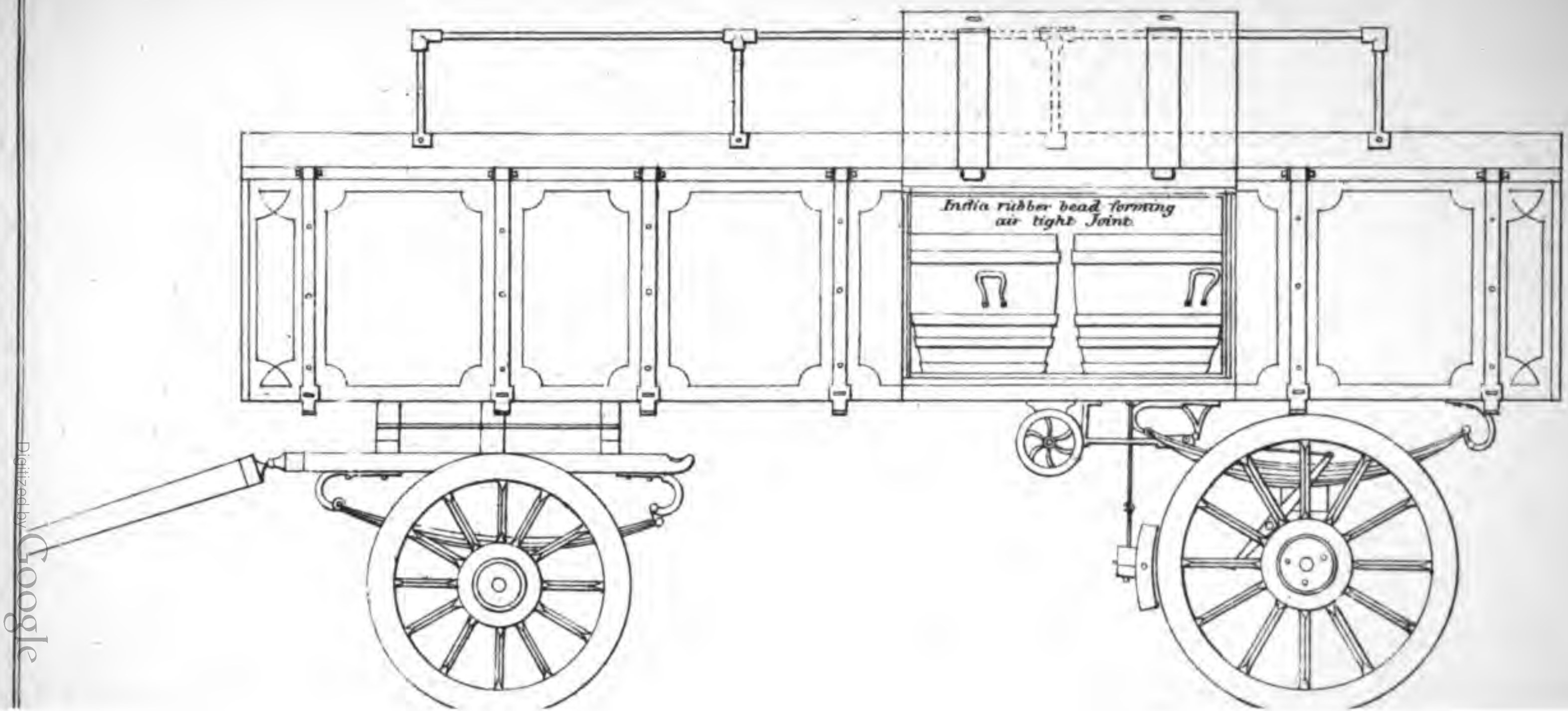
ROCHDALE CORPORATION. SECTION THROUGH SIDE OF EXCREMENT PAIL.



FULL SIZE

ROCHDALE CORPORATION. COLLECTING VAN

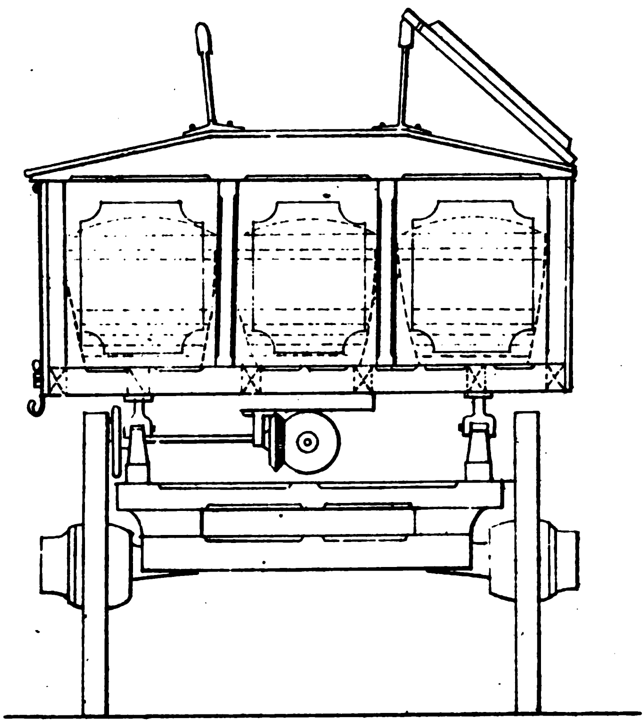
SIDE ELEVATION.



No. 7

ROCHDALE CORPORATION. COLLECTING VAN

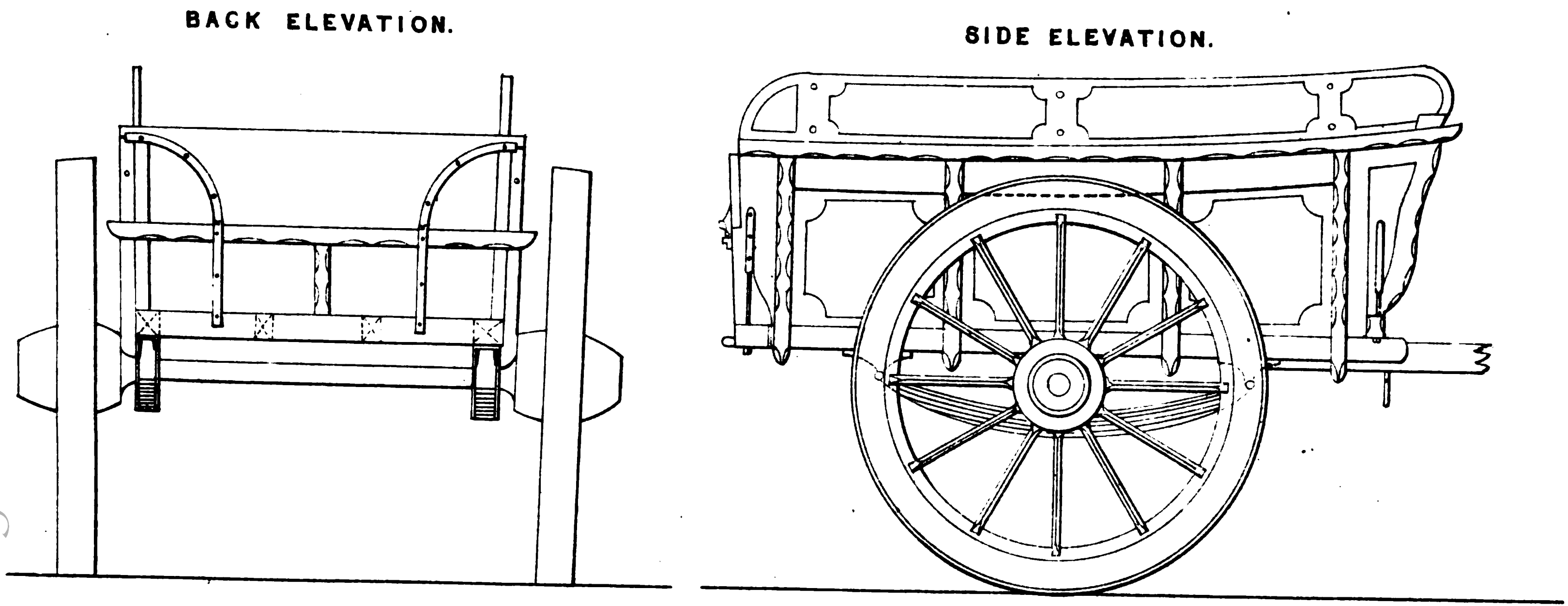
END ELEVATION OF COLLECTING VAN.



Scale, 1 inch - 4 feet.

Dangerfield, Lith. London

ROCHDALE CORPORATION. DUST CART.

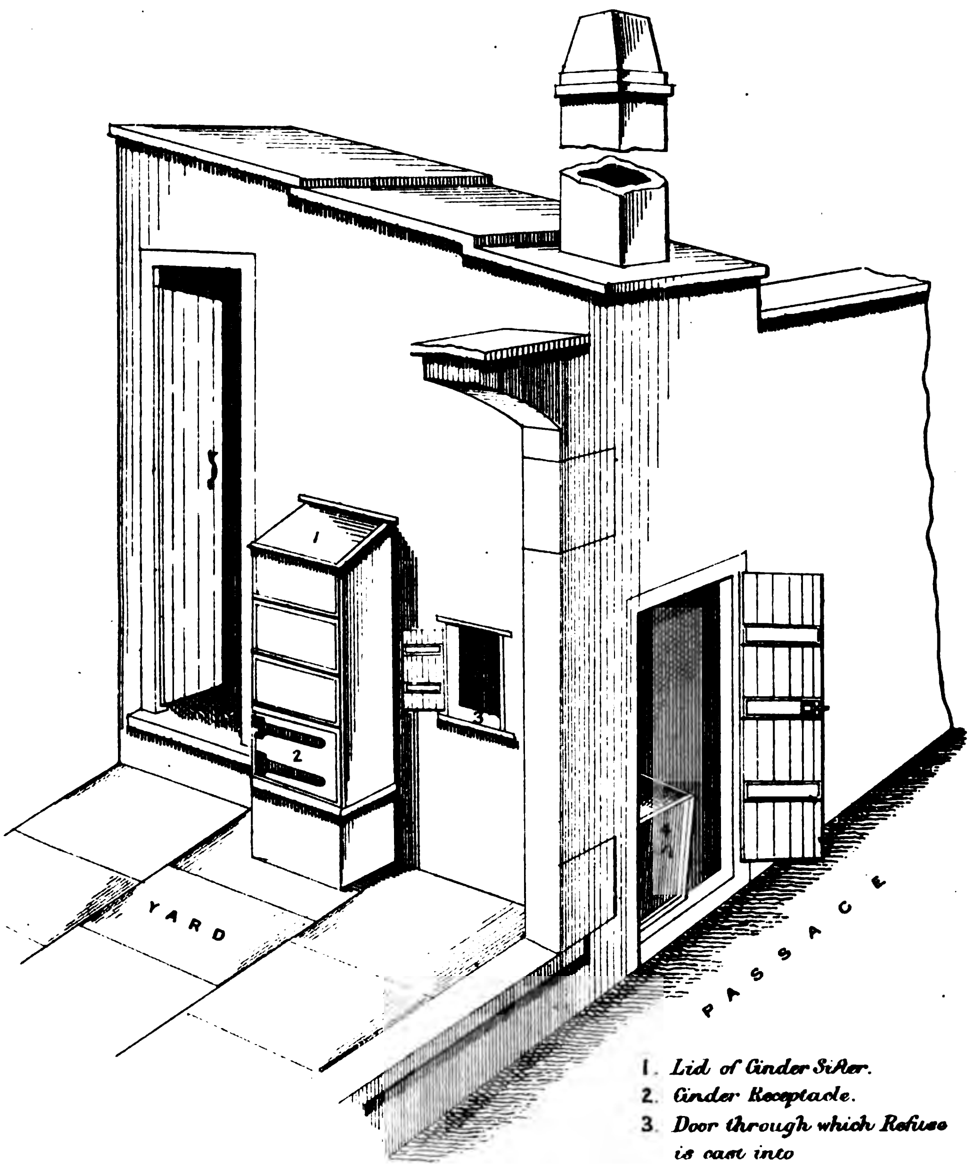


Scale, 1 inch - 4 feet.

No. 1.

MANCHESTER CORPORATION.

DRY ASH CLOSET. ELEVATION.



1. Lid of Cinder Sifter.
2. Cinder Receptacle.
3. Door through which Refuse is cast into
4. Pail for dry House Refuse.

No. 2.

MANCHESTER CORPORATION.

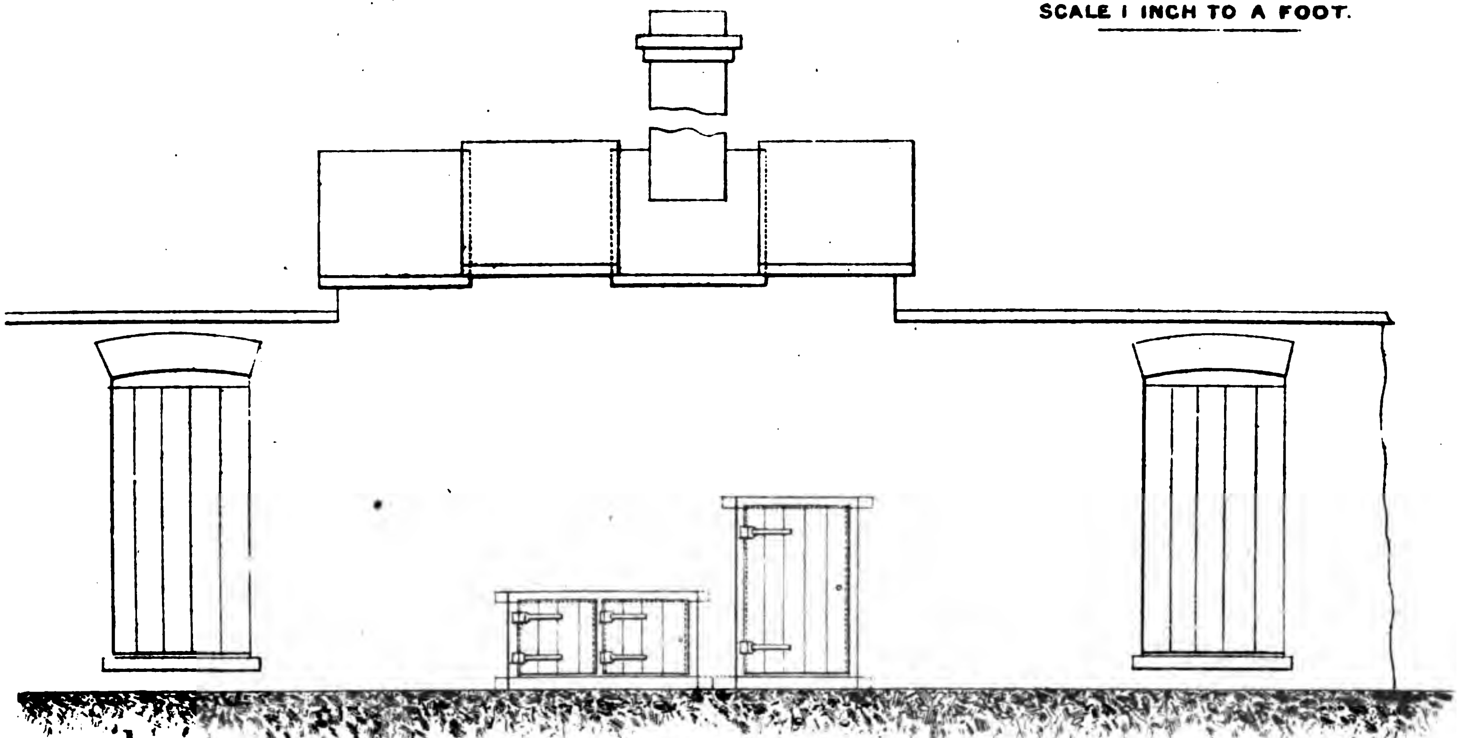
DRY ASH CLOSET.—SECTION.

1. Excrement Pail.

CITY OF MANCHESTER.

DETAIL DRAWING ATTACHED TO SPECIFICATION OF PRIVIES.

SCALE 1 INCH TO A FOOT.



ELEVATION IN PASSAGE

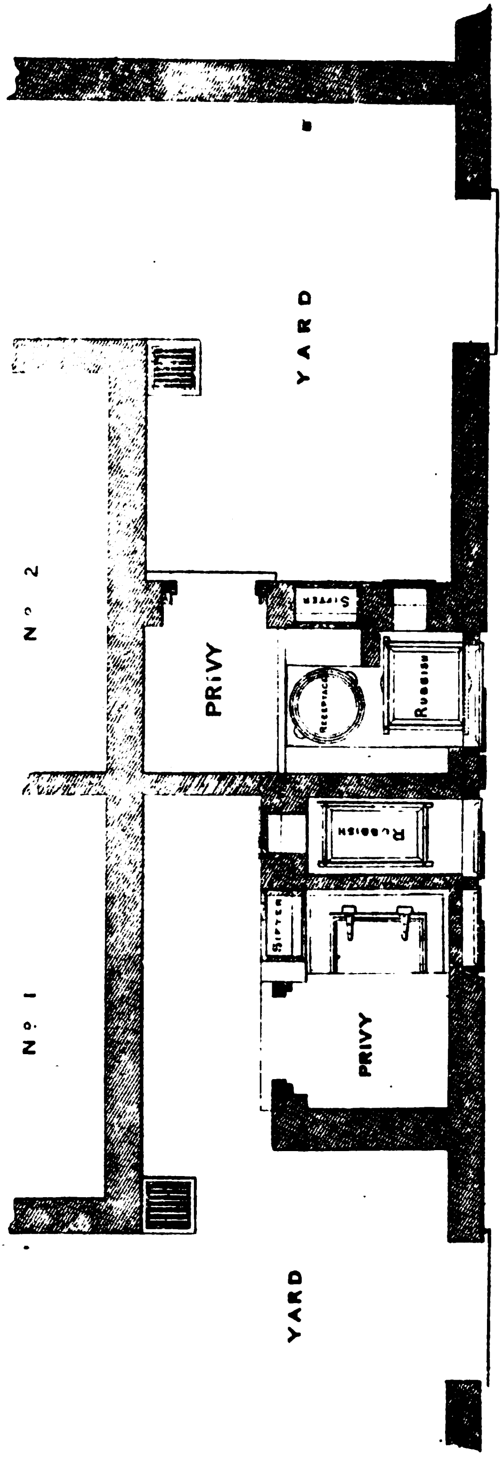
Dangerfield, Lith. Lond.

No 4.

CITY OF MANCHESTER

DETAIL DRAWING ATTACHED TO SPECIFICATION OF PRIVIES.

SCALE 1 INCH TO A FOOT.



GENERAL PLAN

Dangerfield, Lith

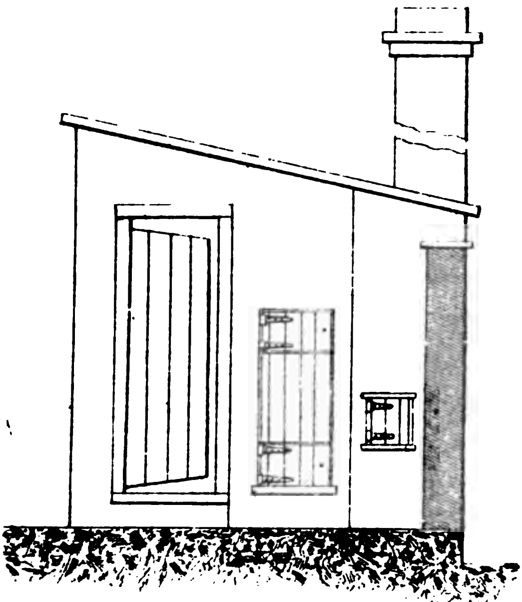
No. 5.

CITY OF MANCHESTER.

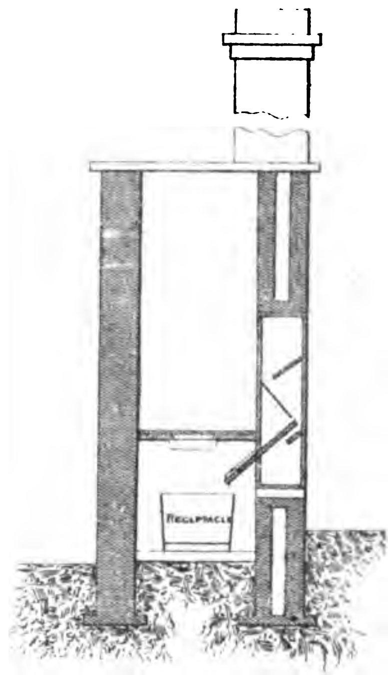
DETAIL DRAWING ATTACHED TO SPECIFICATION OF PRIVIES.

SCALE 1 INCH TO A FOOT.

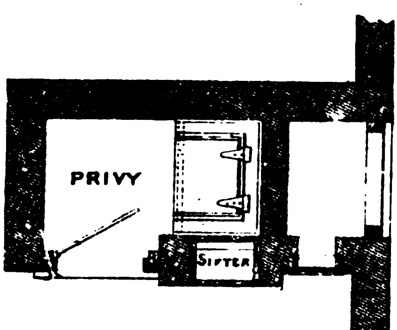
DETAILS OF No. 2



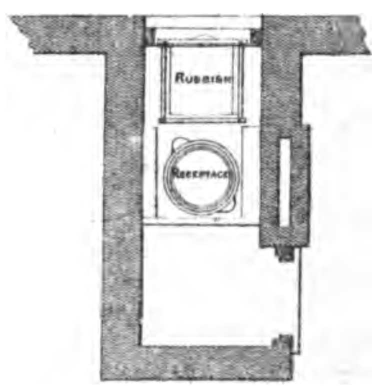
ELEVATION IN YARD



SECTIONAL ELEVATION



PLAN ABOVE PRIVY SEAT



PLAN OF PRIVY FLOOR

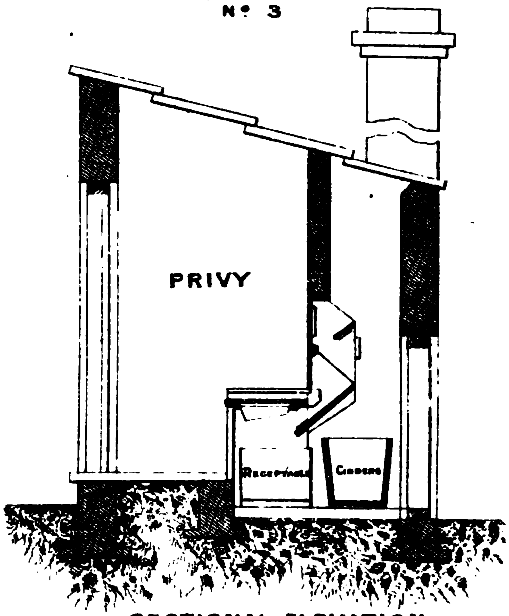
No. 6.

CITY OF MANCHESTER.

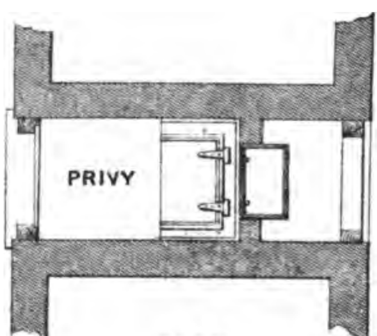
DETAIL DRAWING ATTACHED TO SPECIFICATION OF PRIVIES.

SCALE 1 INCH TO A FOOT.

No. 3



SECTIONAL ELEVATION



PLAN

Dangerfield Lith. London.

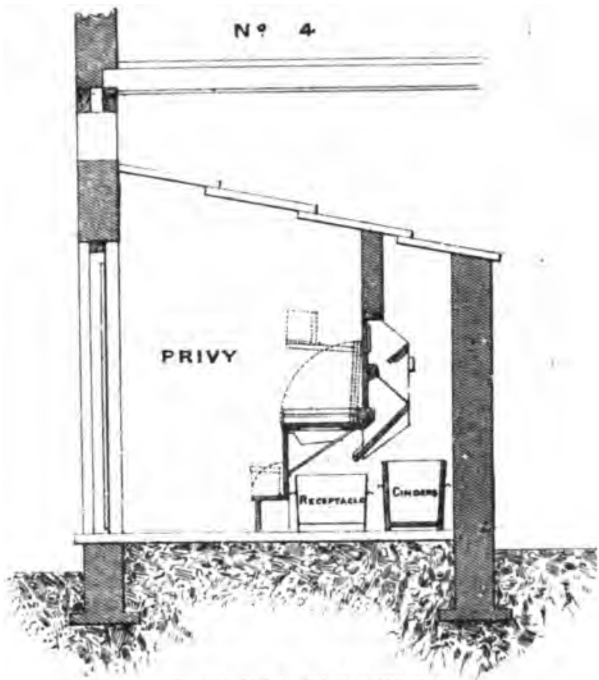
PLATE

No.

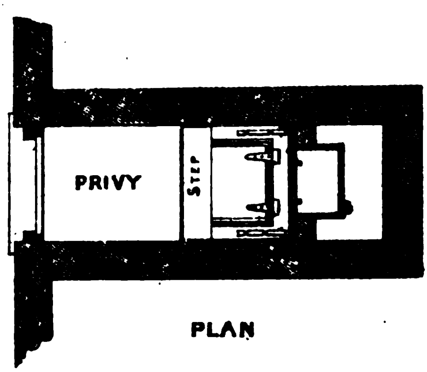
CITY OF MANCHESTER

DETAIL DRAWING ATTACHED TO SPECIFICATION OF PRIVIES.

SCALE 1 INCH TO A FOOT.



SECTONAL ELEVATION.

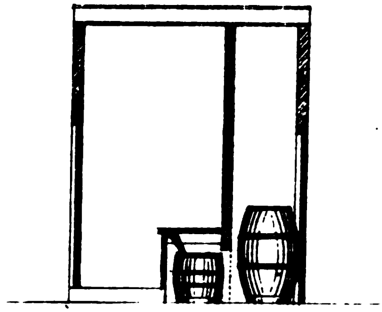


PLAN

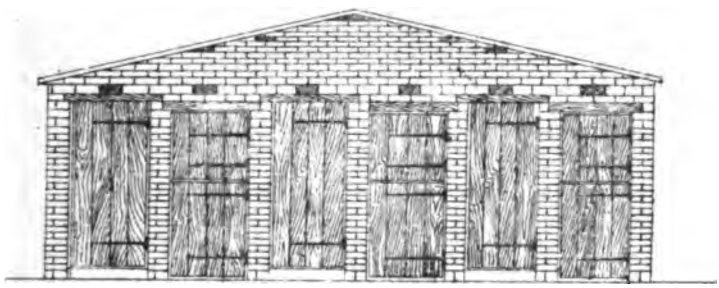
HALIFAX CORPORATION.

No. 1

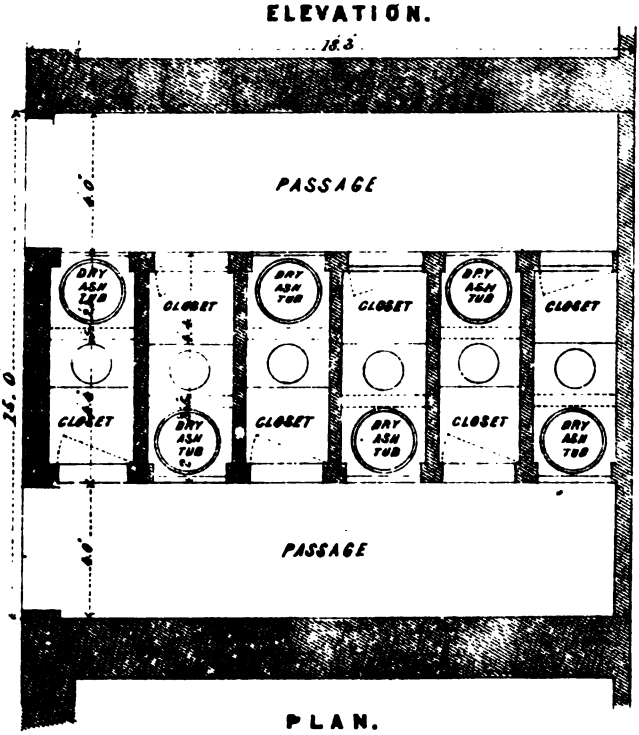
Plan of Gouxc's Closets accompanying specification of Works.–
No. 1. *Suitable for existing back to back Houses.*



SECTION.



ELEVATION.



PLAN.

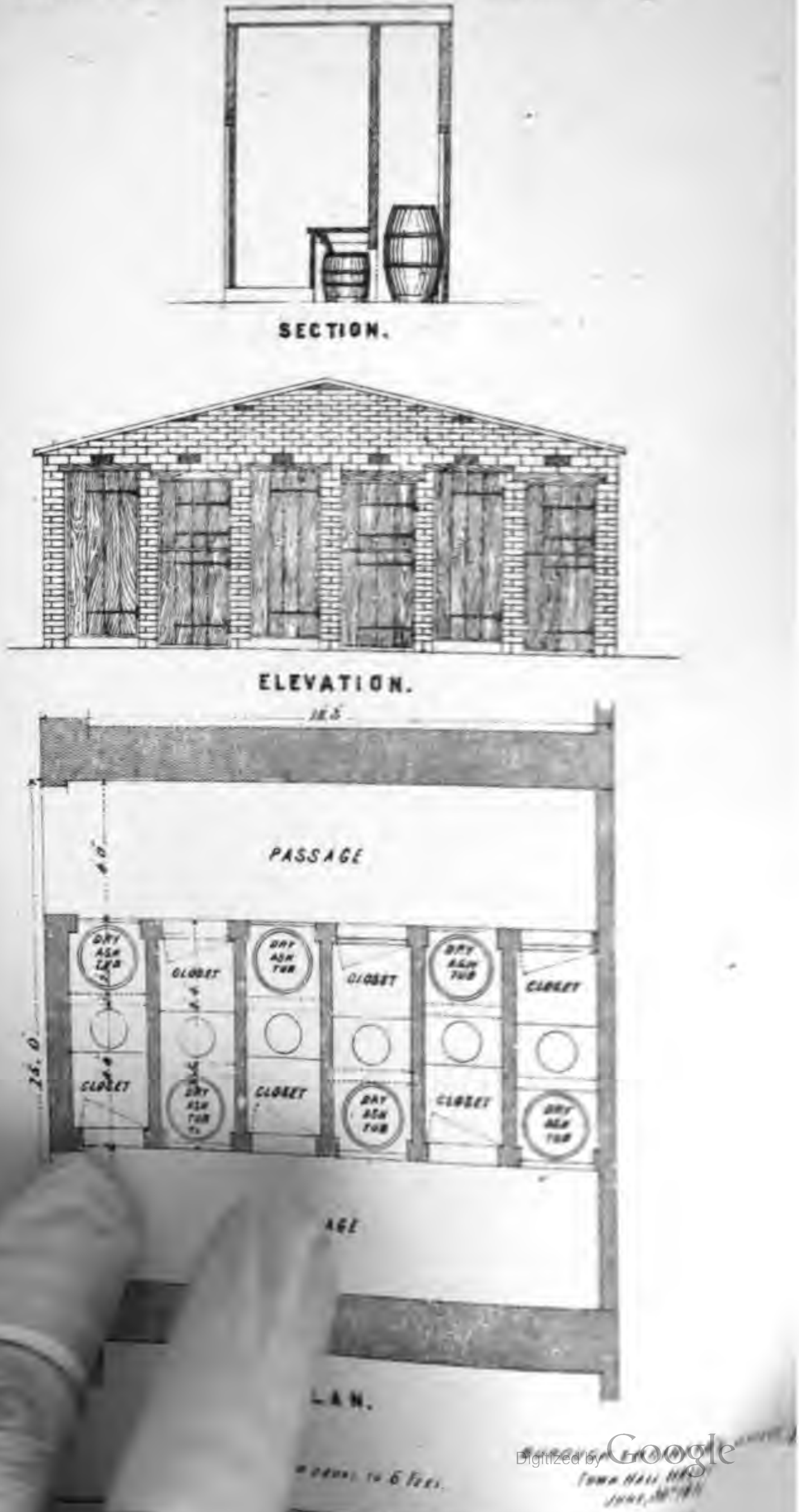
SCALE, 1 INCH EQUAL TO 6 FEET.

BUROUGH ENGINEER'S OFFICE
TOWN HALL, HALIFAX.
JUNE, 30th 1871.

...erfield Lith. London

HALIFAX CORPORATION.

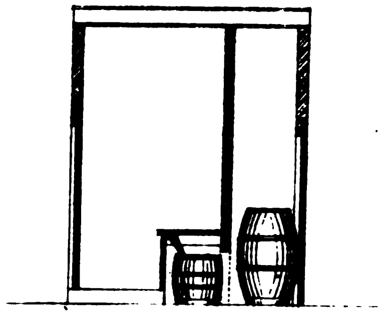
Plan of Goux's Closets accompanying specification of Works —
No 1. *Suitable for existing back to back Houses.*



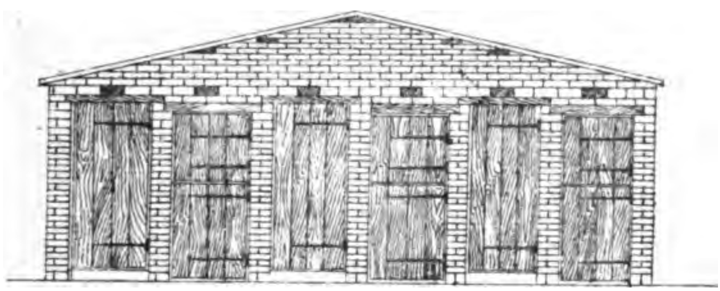
HALIFAX CORPORATION.

No. 1.

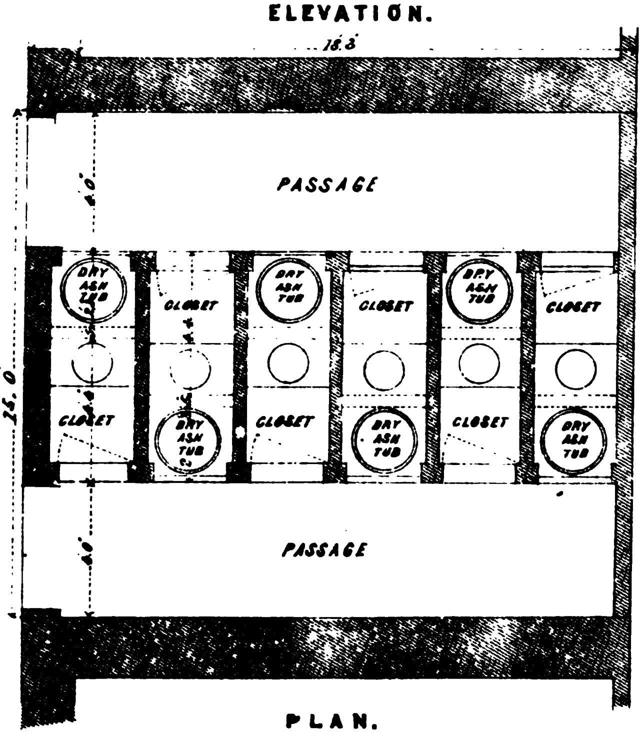
Plan of Goux's Closets accompanying specification of Works.—
No. 1. *Suitable for existing back to back Houses.*



SECTION.



ELEVATION.



PLAN.

SCALE, 1 INCH EQUAL TO 6 FEET.

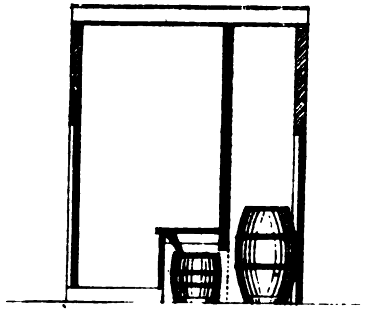
BOROUGH ENGINEER'S OFFICE
TOWN HALL, HALIFAX.
JUNE, 30th 1871.

L[illegible]erfield Lith London

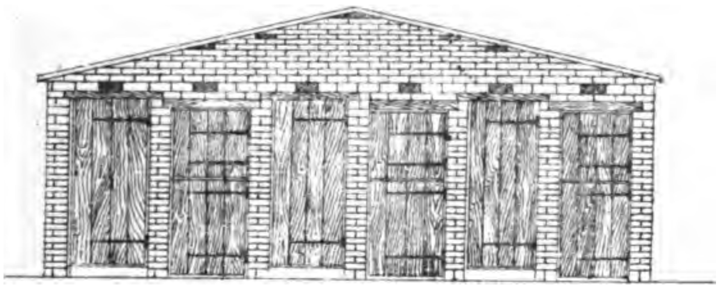
HALIFAX CORPORATION.

No 1

Plan of Goux's Closets accompanying specification of Works.–
No 1. *Suitable for existing back to back Houses.*



SECTION.



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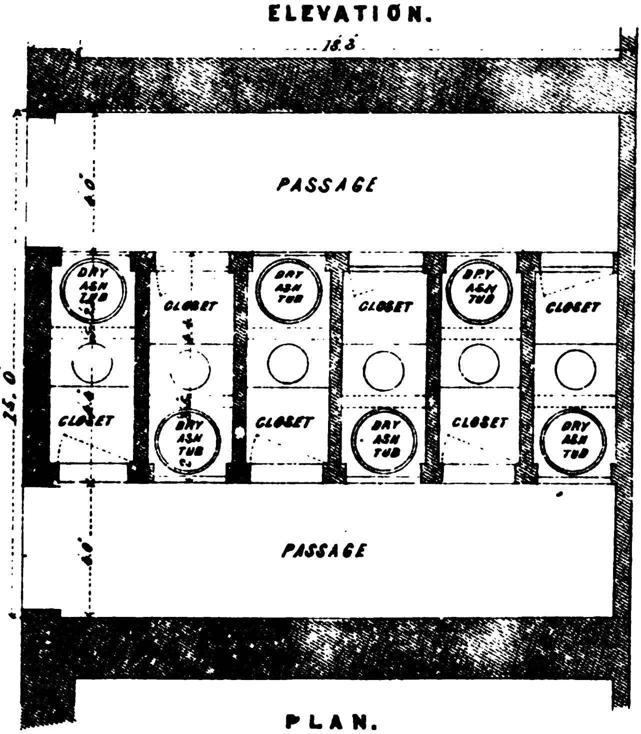

PLAN.

SCALE, 1 INCH EQUAL TO 6 FEET.

BOROUGH ENGINEER'S OFFICE
TOWN HALL, HALIFAX.
JUNE 30TH 1871.

[illegible]erfield Lith London

HALIFAX CORPORATION.

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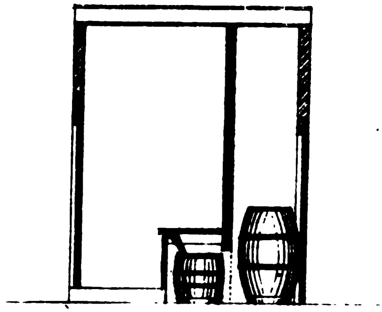

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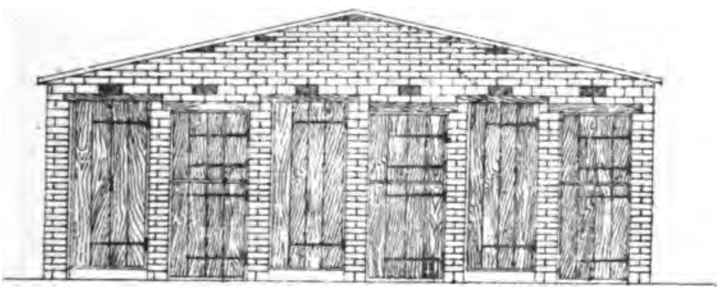

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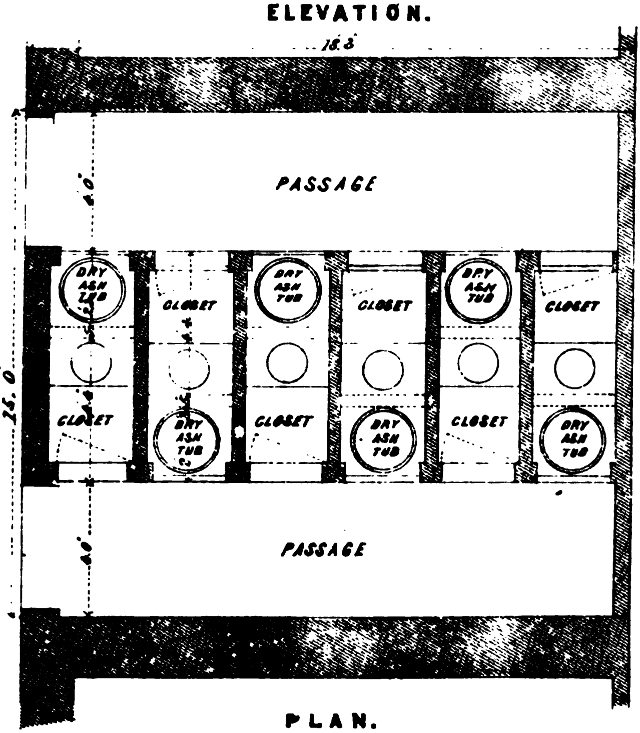


PLAN.

SCALE, 1 INCH EQUAL TO 6 FEET.

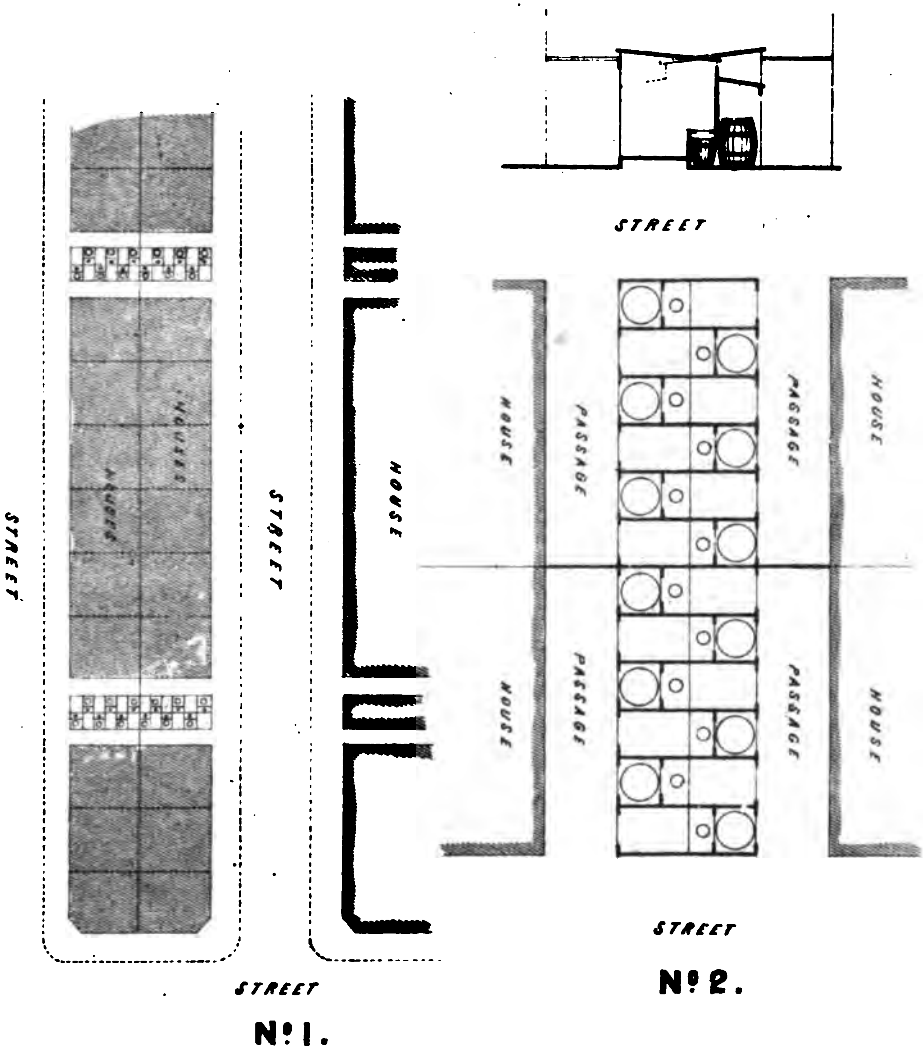
BOROUGH ENGINEER'S OFFICE
TOWN HALL, HALIFAX.
JUNE, 30th 1871.

Leighterfeld Lith London

No. 3.

HALIFAX CORPORATION.

Plans shewing various arrangements of Goux's Closets.



24 Feet = 1 Inch

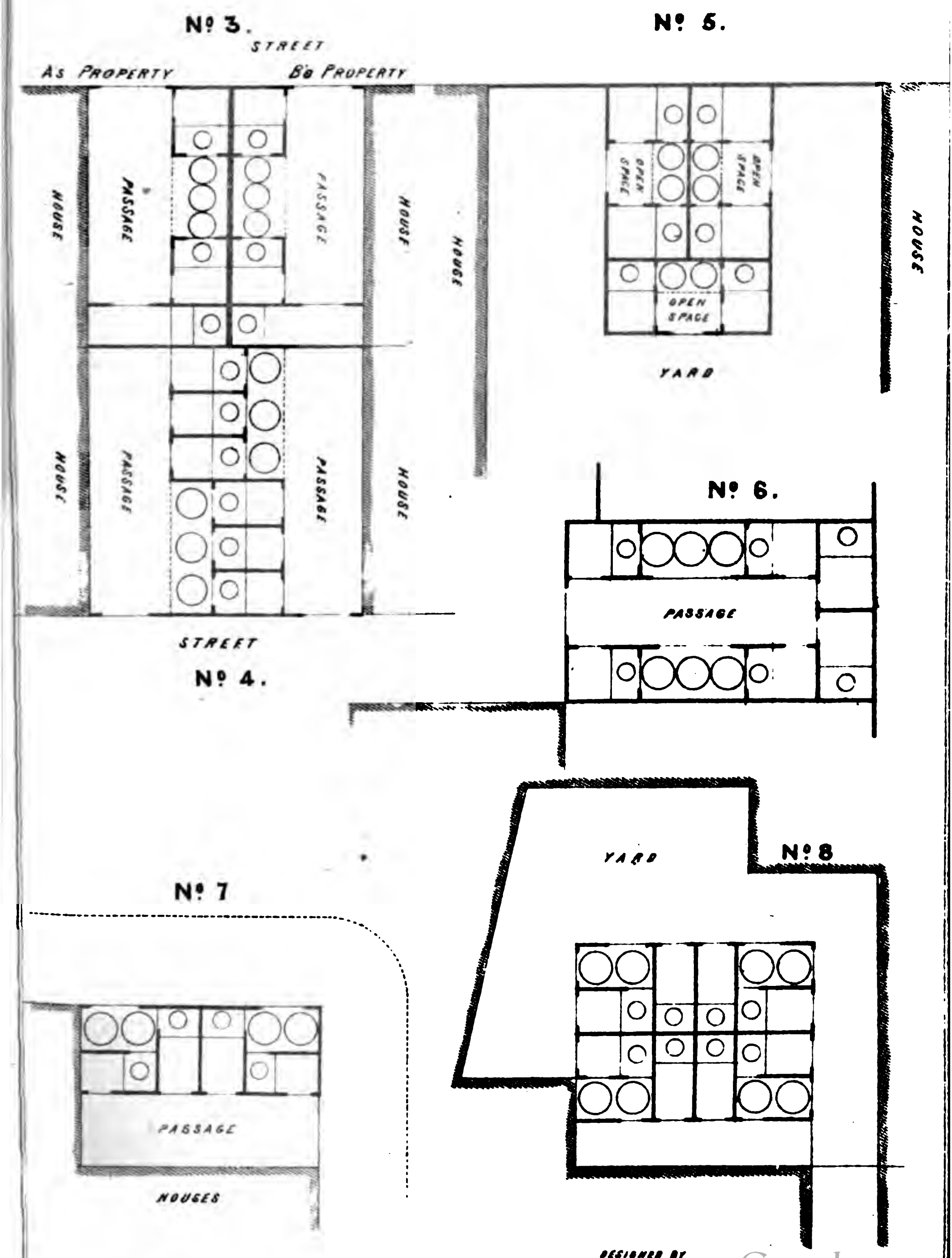
DESIGNED BY
Mr. J. R. SMITH,
SANITARY INSPECTOR,
FOR THE BOROUGH.

Dangerfield Lith. London

No 1.

HALIFAX CORPORATION.

Plan shewing various arrangements of Goux's Closets.

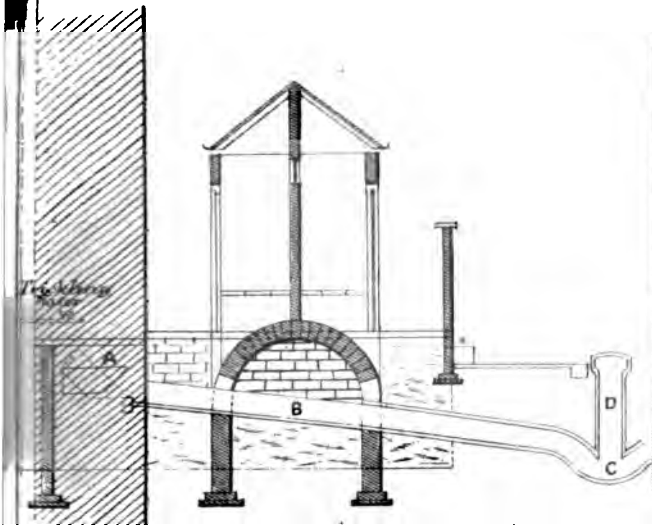


24 Feet = 1 Inch

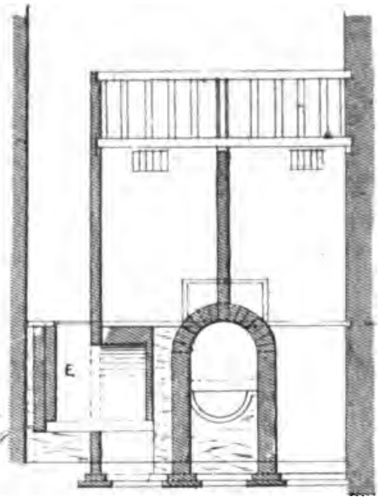
DESIGNED BY
Mr J. R. SMITH,
SANITARY INSPECTOR
FOR THE BOROUGH.

LEEDS CORPORATION.

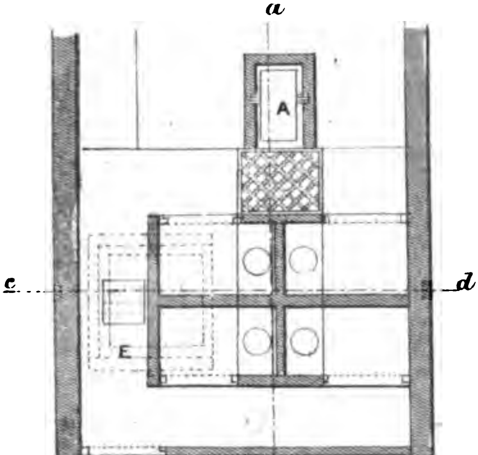
Tumbler Water Closets, Henry Street Leeds.



LONGITUDINAL SECTION (a b)

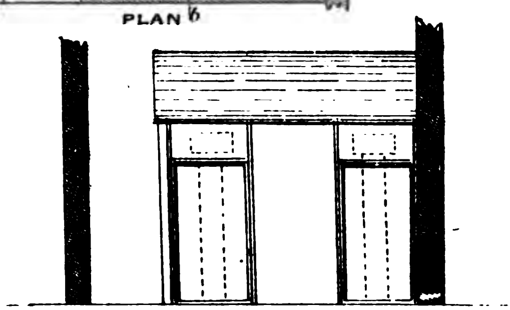


TRANSVERSE SECTION (c.d)



PLAN

A *Tumbler to flush trough.*
B *Trough below 4 Seats shown on Plan.*
C *Syphon trap with (D) cleansing shaft.*
D *Sunk dry ashpit.*



ELEVATION

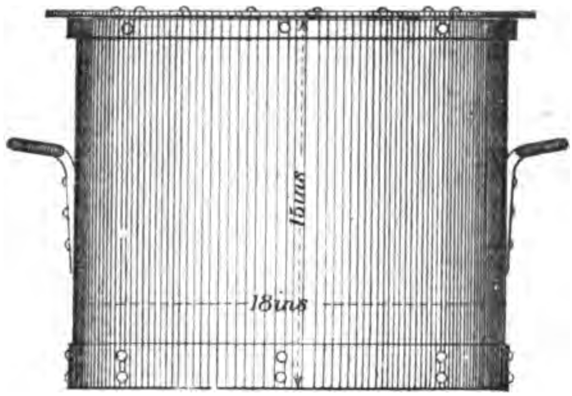
Scale 8 Feet to 1 Inch

12 6 0 1 2 3 4 5 10 15 20 Feet

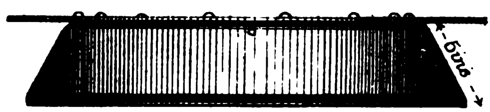
Dangerfield, Lith. London.

BIRMINGHAM CORPORATION.

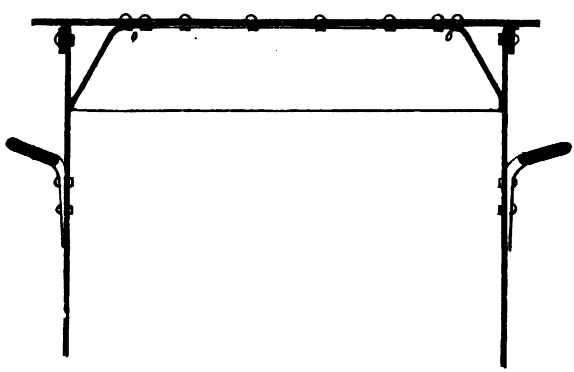
EXCREMENT PAIL.



PAIL.



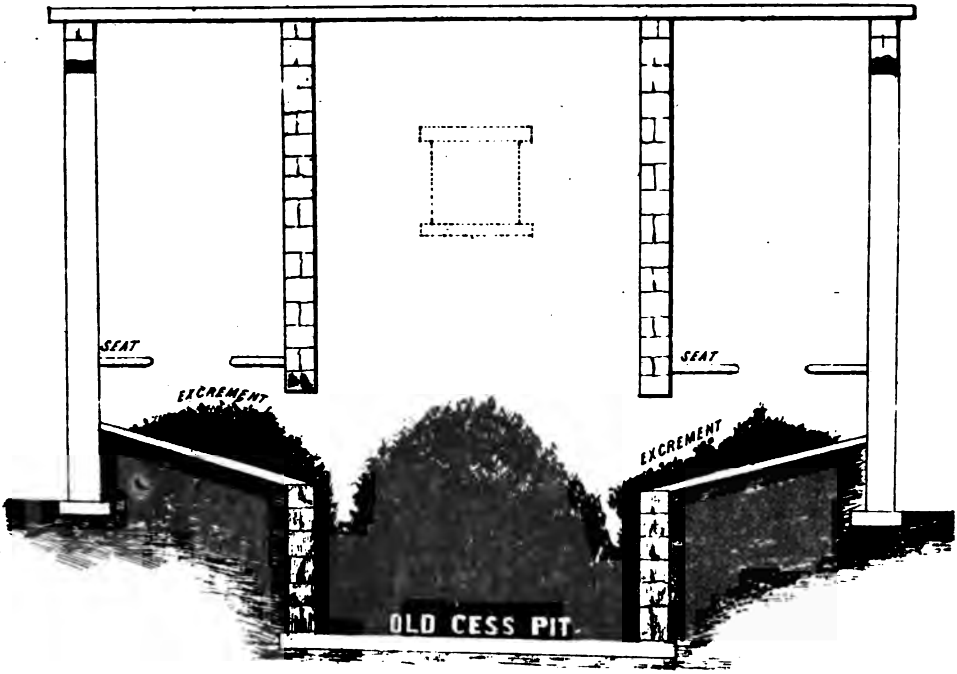
LID.



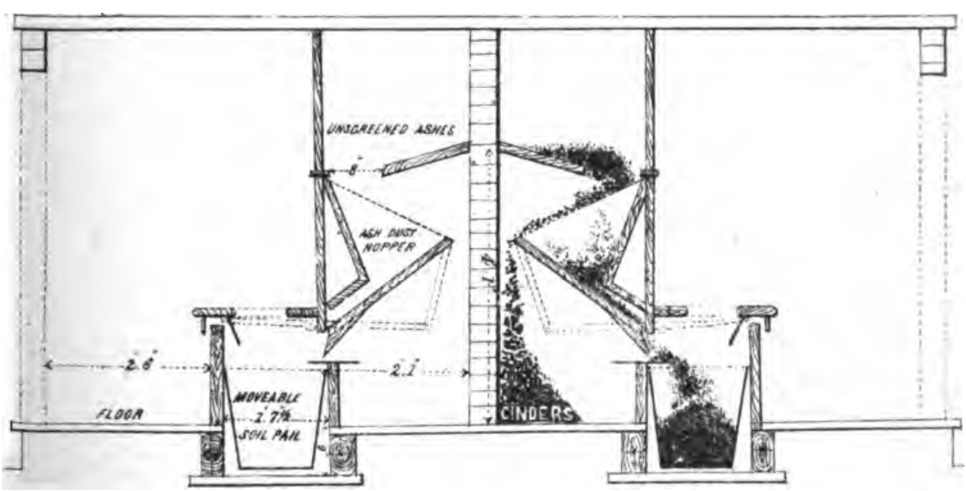
SECTION SHEWING THE LID IN POSITION.

Dangerfield, Lith London.

SALFORD CORPORATION.



Section of old Closets,
Mc Cleary St Pendleton.

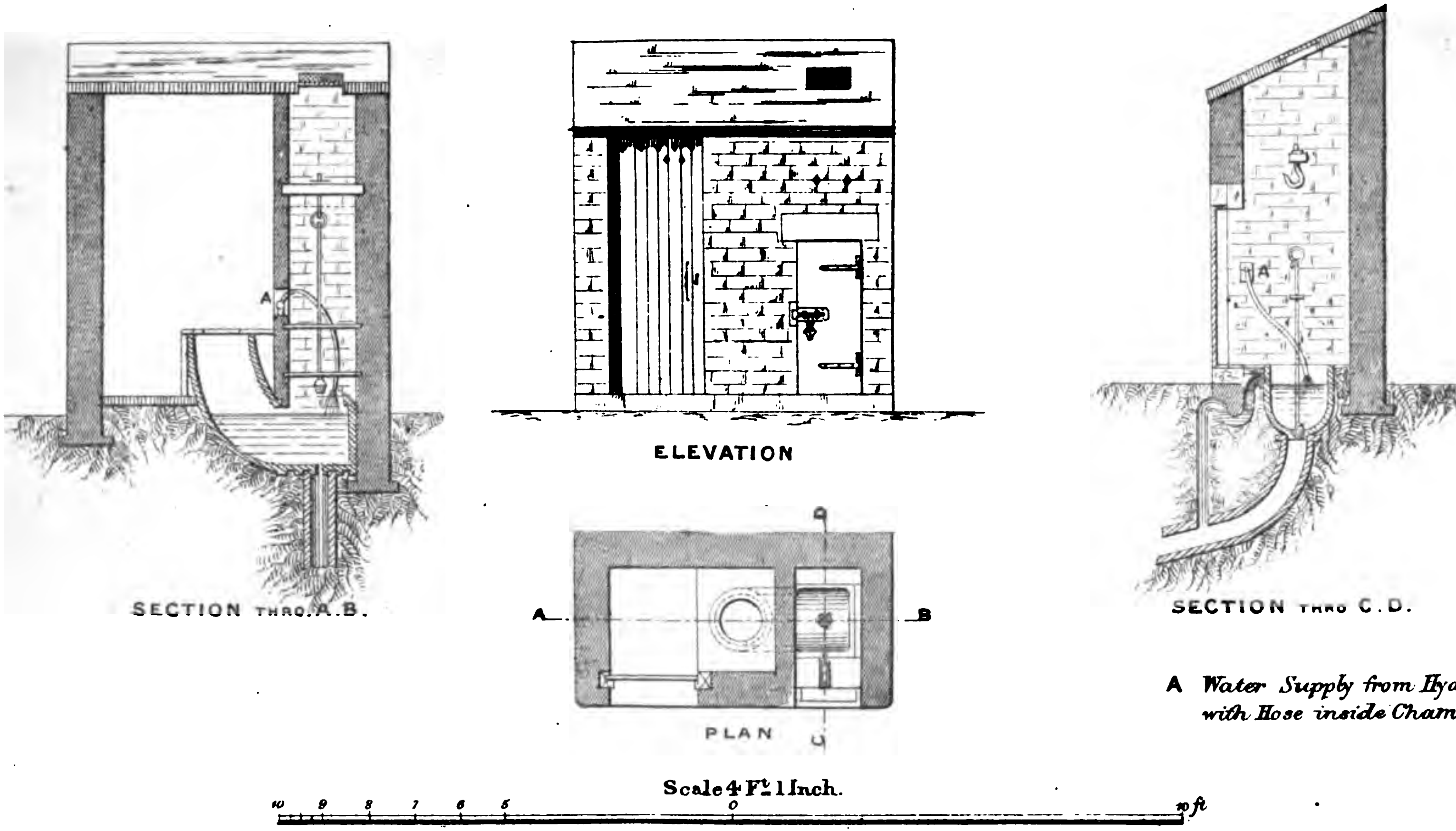


Section of Improved Closets,
with moveable Soil Pan, Morell's arrangement.
Mc Cleary St Pendleton.

Dangerfield Lith I

LIVERPOOL CORPORATION.–TROUGH WATER CLOSET.

No. 1.

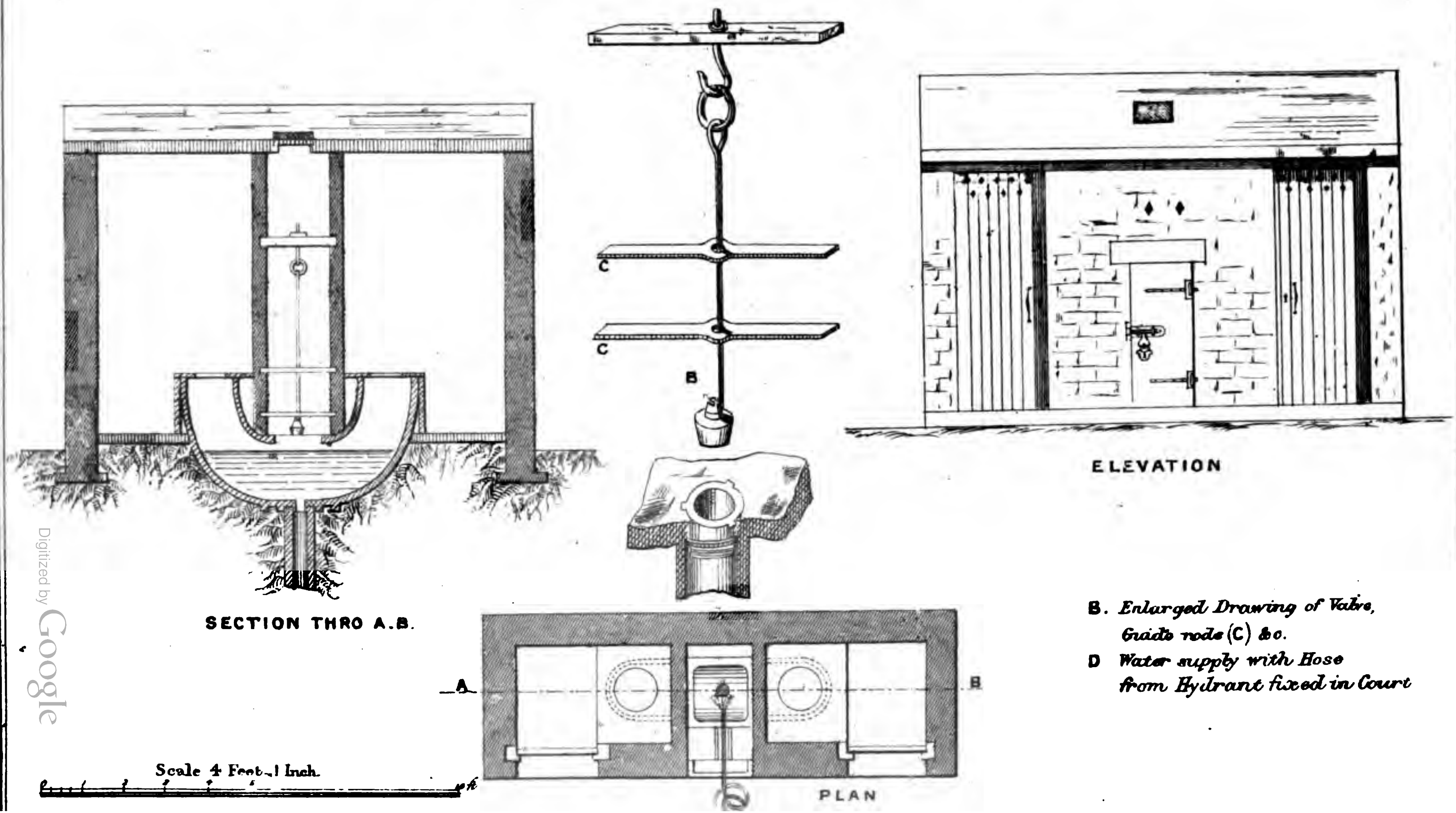


A Water Supply from Hydrant with Hose inside Chamber.

Dangerfield. Lith. London

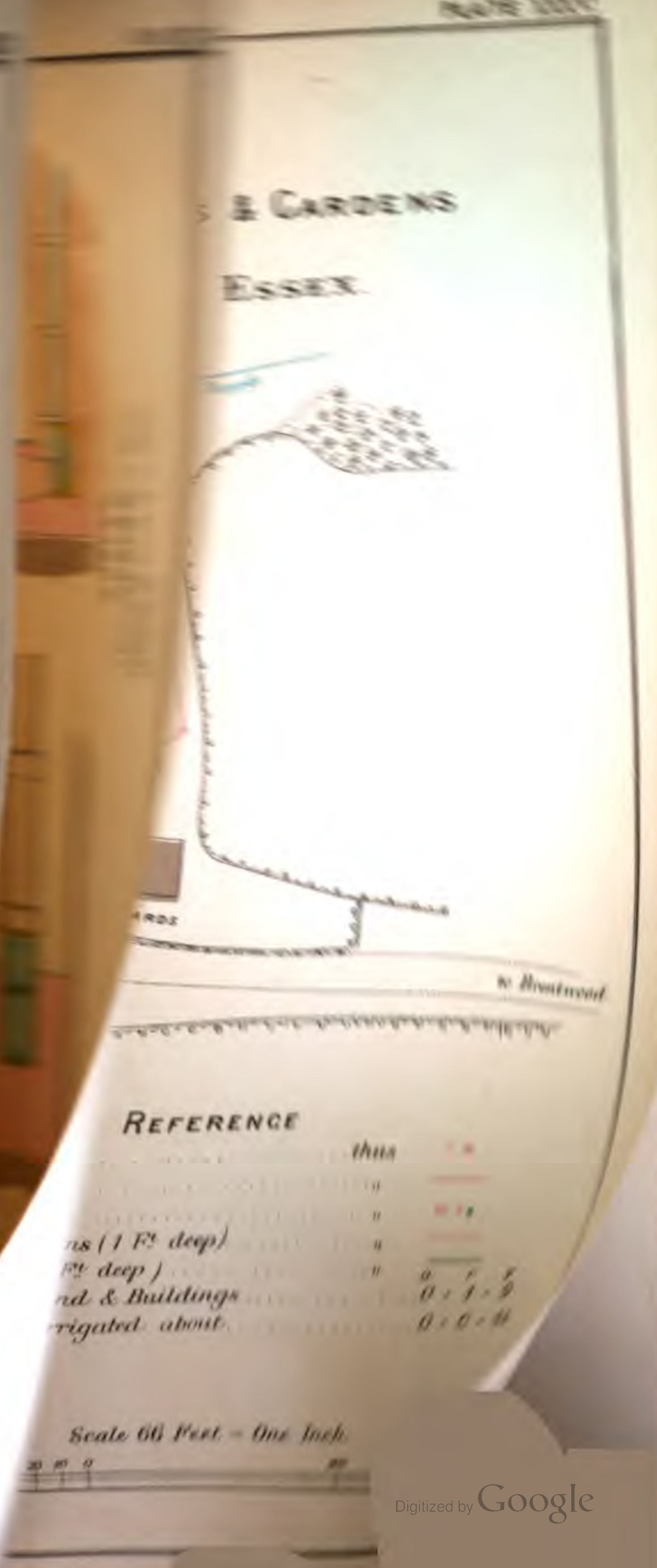
No. 2.

LIVERPOOL CORPORATION. DOUBLE TROUGH WATER CLOSET.



B. *Enlarged Drawing of Valve, Guide rods (C) &c.*

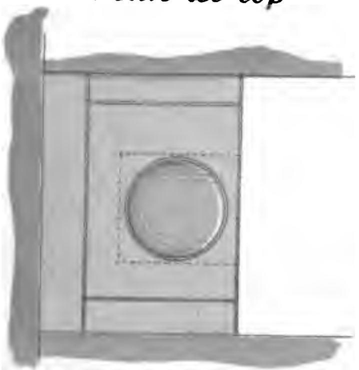
D *Water supply with Hose from Hydrant fixed in Court*


& Gardens
Essex
ards
to Brentwood
Reference
thus
ns (1 Ft deep)
Ft deep)
nd & Buildings
rrigated about
Scale 66 Feet = One Inch

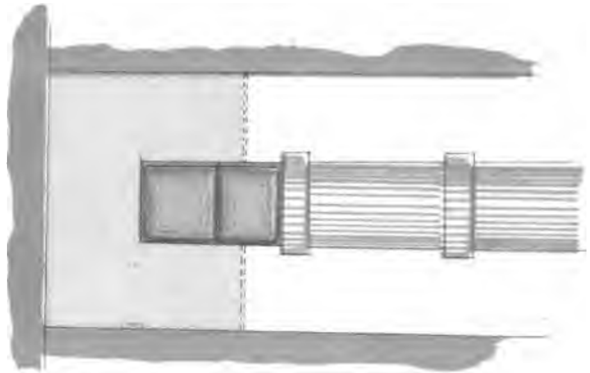
BRISTOL CORPORATION.

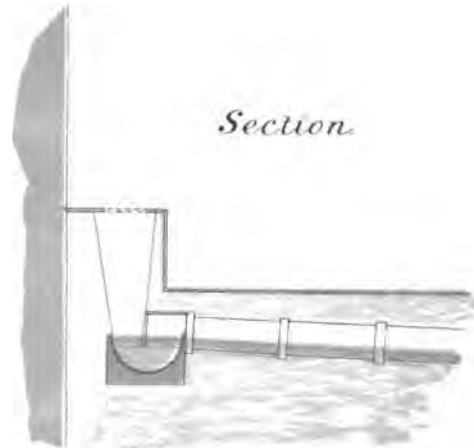
DRAWING OF COMMON PRIVY.

Plan at top



Plan at bottom





REFERENCE.

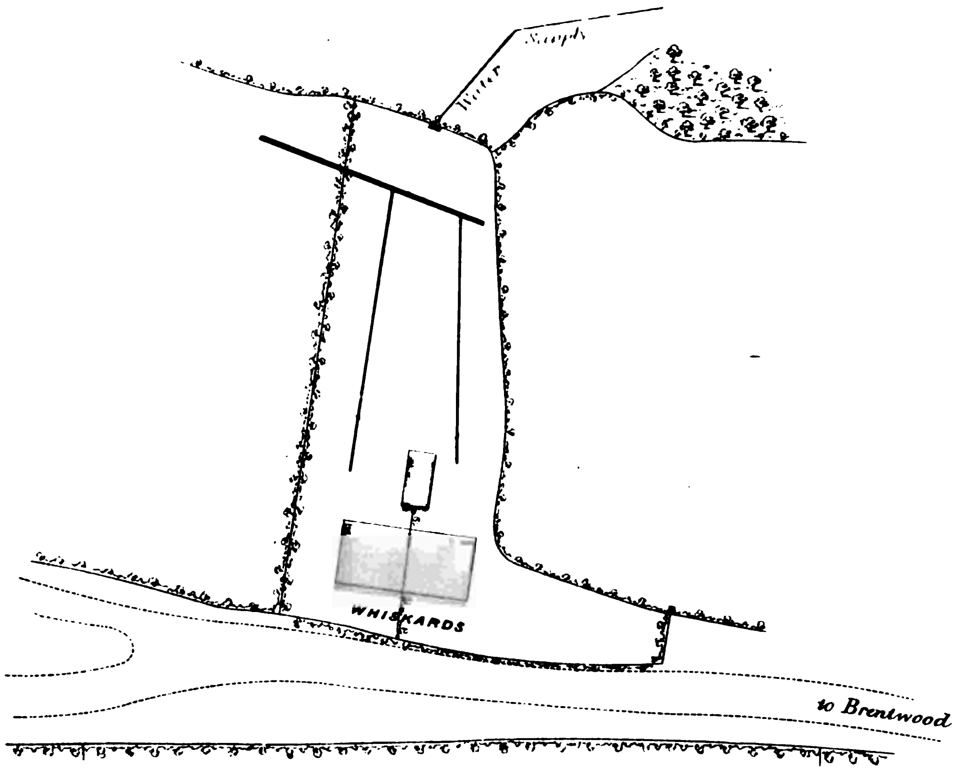
brickwork.
freestone.
woodwork.

SCALES.

Plans ½ Inch to a Foot.
Section ¼ " "

Fields Patent Siphon Tank.

Plan of Cottages & Gardens
at
Shenfield, Essex.



Reference

Siphon Tanks shewn . . . . thus
Watertight Drains . . . . „
Inspection Wells . . . . „
Subirrigation Drains (1 Ft deep) . . . . . „
Land Drains (4 Ft deep) . . . . „

	a	r	p
Total Area of Land & Buildings	0	1	9
Area of Land irrigated about	0	0	14

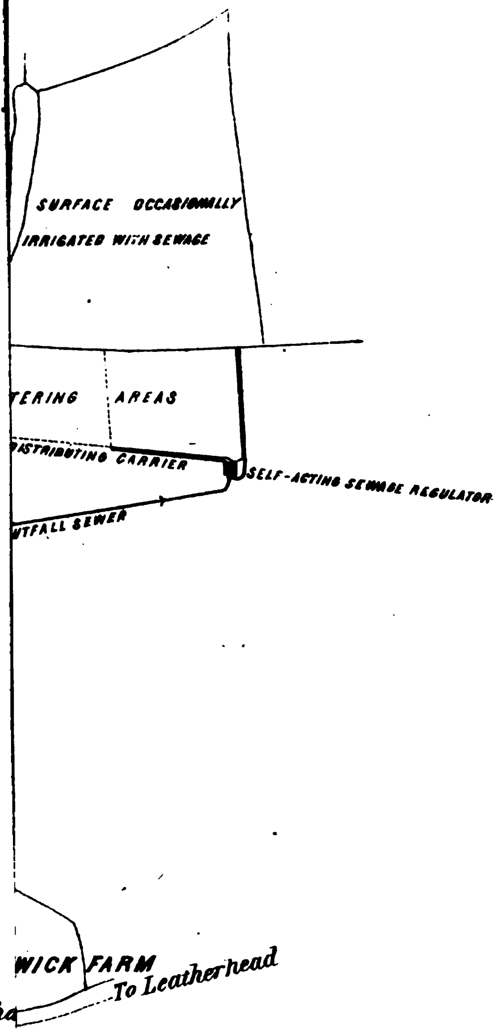
Scale 66 Feet – One Inch.

100 90 80 70 60 50 40 30 20 10 0 100 200 FEET

5 Cannon Row, Westminster. Septr 1873.

Dangerfield Lith London.

MAP OF



J. BAILEY DENTON
22 WHITEHALL PLACE,
LONDON.

Dangerfield Lith, 22, Bedford St. Covent Gar

PUBLIC HEALTH.

REPORTS

OF

THE MEDICAL OFFICER OF THE PRIVY COUNCIL AND LOCAL GOVERNMENT BOARD.

NEW SERIES, No. III.

REPORT TO THE LORDS OF THE COUNCIL ON SCIENTIFIC INVESTIGATIONS, MADE UNDER THEIR DIRECTION, IN AID OF PATHOLOGY AND MEDICINE.

Presented to both Houses of Parliament by Command of Her Majesty.

LONDON:
PRINTED BY GEORGE E. EYRE AND WILLIAM SPOTTISWOODE,
PRINTERS TO THE QUEEN'S MOST EXCELLENT MAJESTY.
FOR HER MAJESTY'S STATIONERY OFFICE.

1874.

[C.—1068.] *Price* 1*s*. 4*d*.

CONTENTS.

MEDICAL OFFICER'S REPORT.

To the LORDS of HER MAJESTY'S MOST HONORABLE PRIVY COUNCIL.

MY LORDS,

MEDICAL OFFICER'S REPORT.

IN continuation of former reports, referring to Scientific Investigations made under your Lordships in this Department, I have now the honor of laying before your Lordships the subjoined five papers, and would beg leave to prefix to them a few introductory words, first, with regard to the branch of work to which the papers belong, and then with regard to the papers respectively.

The purpose of the Scientific Investigations which are made in this Department is to contribute in a particular way to the progress of the Art of Medicine.

The sorts of study by which the Medical Profession hopes to extend its means of usefulness to mankind, whether as regards the cure of individual cases of disease, or as regards those large acts of preventive medicine which are of interest to masses of population, may broadly be distinguished as two. On the one hand, there are studies which every member of the Medical Profession (more or less according to his circumstances) has both opportunity and inducement to cultivate at least for his own use, and generally for that of others, by intelligent observation and record of the facts which come before him in his daily practical work, and by scientific generalisations from such experience; and I need hardly observe that, from studies of that sort, which are a life-long happiness to innumerable medical practitioners, the aggregate efficiency of the Profession is always in course of increase. On the other hand there are extremely important studies, for which the ordinary professional practice supplies neither opportunity nor immediate stimulus; studies, namely, of elaborate and purely scientific research in aid of the development of medical knowledge; studies never immediately convertible to pecuniary profit, but perhaps, on the contrary, involving heavy cost; studies, too, which from their nature cannot promise rapid results, nor be conducted in fragments of leisure, but require systematic and continuous labor extending over long periods of time.

It cannot be expected that studies of this latter sort, even where of the highest eventual importance, should generally be cultivated to any adequate extent by private medical investigators; and the distinctive intention of the Scientific Investigations which are conducted under your Lordships' auspices has been to supplement in that direction the ordinary resources of private medical observation. It is of the essence of the case that the work does not pretend to immediate popular application, but addresses itself

primarily to the deeper scientific requirements of the Medical Profession, and is therefore in an extreme degree technical. It is also of the essence of the case that, in common with everything which is tentative, the work may sometimes have its turn of temporary unsuccess and disappointment; and that therefore its results (as indeed the results of every scrupulous scientific investigation) are less suited to be measured from year to year than in terms of several years taken together.

The work which is at present in progress is an exceedingly large and various study, having many divisions and subdivisions of its own, and sometimes (as will be seen) involving collateral inquiry, but nevertheless, in its intention, quite definite and single. It aims to be a systematic study of the intimate pathology of the *Morbid Infections*, acute and chronic.

Such study in regard of any one infection has of course several lines of investigation: for, on the one hand, the infective agent has to be identified; and, on the other hand, the successive changes which it effects in the living body have, from beginning to end, to be made intelligible. Then, scientifically speaking, no morbid change in the body can be stated in intelligible terms except with exact comparative reference to health as a standard; and in the present case the things and processes as to which the questions of comparison arise, and which belong to the subtlest subject-matters of physiological research, are hitherto, in a large part of the field, but very imperfectly known as to their normal standards: so that, to this large extent, an indispensable preliminary to progress in the pathological study is at least to verify and complete the required physiological standards of comparison, and in not a few cases to invent new methods of procedure by which observations so subtle may be conducted.

Without pretending to prejudge exactly what may be the eventual application of each addition made to scientific knowledge, I may observe in general terms that some physiological and pathological work seems rather to connect itself with the hopes of Preventive, other rather with the hopes of Curative, Medicine. Every process of disease admits of being contemplated and investigated from either of two opposite points of view: either, namely, from the side of the morbific cause, and with particular reference to the initiatory acts of disease; or from the side of the final morbid effect, and with particular reference to the modes of operation by which disease tends to destroy life. Researches in the former sense may peculiarly be expected to increase our powers of preventing disease, and researches in the latter sense to suggest improvements in therapeutical practice.

It is chiefly from the former of those points of view that Professor Sanderson has for some years been working under your Lordships in one large part of the Scientific Investigations; in which

division of the field he has of late been very ably seconded by Assistant-Professor Dr. Klein, and on the present occasion also presents a contribution of much interest by Dr. Creighton.

Of the annexed papers the first two, respectively by Dr. Sanderson and Dr. Klein, relate to the intimate ætiology of the acute infective diseases. Ten years ago we had not even a beginning of any true insight into the respective *Contagia* which excite those diseases; and considering the large and lasting interest which exact studies in this field of scientific research must have for the human race, I think the fact noteworthy that the first of such studies were instituted, and the first steps of discovery made, with reference to a contagious fever of horned cattle. I refer, namely, to the researches which were made under Her Majesty's Government in 1865 in aid of the then Cattle Plague Commission: when Dr. Beale, working at the microscopy of the disease, drew attention to the swarms of extremely minute particles which he found universally present in the textures and juices of the animals, and which he believed to be the contagium of the disease; and when Dr. Sanderson, working at the matter from a different point of view, succeeded in showing experimentally that the true contagium admits of being physically distinguished in the animal juices which contain it, and of being so separated from them as to leave them without infective power. In the next succeeding years, the writings (to which I have on former occasions adverted) of Dr. Hallier, Professor of Botany in Jena, brought under animated discussion, as a branch of micro-phytology, the nature and mode of origin of contagium-particles in a great variety of diseases, human and brute: new experimental knowledge of several contagia was set forth in the writings (to which also I have before referred) of Professor Chauveau, of the Veterinary School of Lyons; and in 1870 I had the honor of presenting Dr. Sanderson's first report of researches made in the matter under your Lordships' direction. At that time, general conclusions already seemed justified; first, that the characteristic shaped elements, which the microscope had shown abounding in various infective products, are self-multiplying organic forms, not congeneric with the animal body in which they are found, but apparently of the lowest vegetable kind; and, secondly, that such living organisms are probably the essence, or an inseparable part of the essence, of all the contagia of disease. The study of morbid contagion was thus brought into seeming affinity with that which had for some years before been made by Professor Schröder and M. Pasteur in the ordinary processes of fermentation and putrefaction; and there began to become faintly visible to us a vast destructive laboratory of Nature, wherein the diseases which are most fatal to animal life, and the changes to which dead organic matter is passively liable, appear bound together by what must at least be called a very close analogy of causation. This view of the matter has since then become greatly more distinct in consequence of investigations made under your Lordships by Dr. Sanderson, particularly in 1871 and

1872, with reference to the common septic contagium or ferment;* for in that ferment, particulate as above described, there seems now to be identified a force which, acting disintegratively upon organic matter alike whether dead or living, can on the one hand initiate putrefaction of what is dead, and on the other hand initiate febrile and inflammatory processes in what is living.

Continuation of this line of study in regard of acute infections of the living body is represented in the first two of the appended papers.

In the first paper Dr. Sanderson brings down to the present time an account of the *Microphytes of Contagion*; setting forth more particularly such positive knowledge as has yet been obtained with regard to the respective contagia and respective morbid processes of diphtheria, erysipelas, relapsing fever, and (though but rarely a human disease) the splenic fever or "milz-brand" of veterinary practice.

The second paper represents a contribution to the growing modern doctrine of contagion, in an exposition by Dr. Klein of the intimate nature of the local changes which characterise the acute zymotic disease known as *Variola Ovina* or *Sheep-Pox*. Dr. Klein has been able to identify the contagium-particles of that infectious fever as definite microphytes, growing and fructifying with vast rapidity in the canals and tissues of the infected skin: the woodcuts of his annexed paper show the process to have been observed by him with a completeness not yet, I believe, attained in regard of any other such case: and these results of his, while they complete as regards the special disease in question the broad pathological outline which previous inductions had rendered probable, must also, I think, be regarded as tending very importantly to confirm, while they illustrate, the general doctrine of the vitality of contagia.

The third of the annexed papers, also by Dr. Klein, and founded on work of his which has been in progress for more than two years, continues a line of research already much worked by Dr. Sanderson, with regard to the most important of all chronic infective processes: that, namely, which is at the root of the so-called *Tubercular Diseases* of the animal body, and which has its highest practical interest in relation to the pulmonary phthisis of the human subject. In my Report of 1868, I had to mention to your Lordships an infinitely interesting light of new knowledge with regard to tubercular disease, in the discovery which M. Villemin had recently made, and which other observers had immediately confirmed, of its being inoculable from subject to subject. During the years which have since passed, further and very striking illustration of the communicability of tubercle has

* For convenience, in speaking of this morbific influence, I use the singular number, but have no intention of implying that ordinary putrefactive changes have only one ferment which can be considered habitual to them.

been given by the results of experimental feeding with the milk of living tubercular animals, or with bits of diseased texture from such animals when dead; it having been found that in the subjects of such experiments the contagium penetrates by the absorbent organs of the alimentary canal, and so diffuses from them its influence to other organs of the body as to produce general tubercular disease.* With my Reports of 1868 and 1869 I submitted to your Lordships important papers by Dr. Sanderson on the studies which had then been made of tubercle in its infective relations; and the paper by Dr. Klein which I now submit gives a second series of results in the same subject-matter. It has from the first been a necessary part of the researches into the processes of tubercular infection in the animal body, that very exact study should be made of the intimate anatomical conditions which determine the sequence of its phenomena and make different organs differently susceptible of it. In the earlier researches Dr. Sanderson found himself obliged for this reason to make much anatomical study of the lymphatic glands; and in the later researches it was an indispensable first need that the knowledge of the lymphatic system should be completed by an exhaustive investigation of the radicles and gland-rudiments of that system in at least the serous membranes and the lungs. Dr. Klein's fulfilment of that large preliminary task has added very valuably to previous knowledge of the normal anatomy; but in the accompanying paper, which essentially relates to the course of tubercular infection in the organs referred to, these results of his two years' work are only given with such amount of detail as may make the morbid anatomy quite intelligible.†

The broad results of modern discovery in regard of ordinary tubercular disease tend to represent it as a chronic locally-originated zymotic process, which, starting under certain conditions in one first spot of the (predisposed) animal body, advances by successive steps in definite anatomical lines to infect the entire system: a process, which by means of its characteristic products is inoculable from part to part, and from subject to subject; but of which in certain other cases the locally originating cause or contagium appears to be the common septic ferment, or a ferment not yet separable from the septic.‡ This

* In this connexion it deserves notice that within the last few weeks Dr. Hermann Weber has brought before the Clinical Society some facts of a strikingly suggestive kind as to the possibility of tubercular infection being freely communicated to women through their conjugal relations with men who have pulmonary phthisis in a quiescent or very chronic state.

† I may note that these studies of Dr. Klein's, and also that relating to Sheep-Pox, were completed at a time when my former series of reports had come to an end and the plan of the present series was not yet settled; and that, as it was desirable not to delay scientific publication of the results, the papers were, with their Lordships' sanction, communicated at once to the Royal Society.

‡ That the acute tuberculisation of organs is preceded by an infection of the blood is made in the highest degree probable by a consideration of the circumstances of cases: but, as to the source from which this infection would first have come, evidence enough for judgment is not yet given.

being the tendency of recent knowledge in regard of tubercle, evidently there must arise from it very important suggestions (on which I need not here dwell) both as to further like studies of the same disease, and as to tentative applications of the knowledge in the province of preventive medicine; and suggestion also arises with regard to a collateral interest scarcely less important than that of tubercle.

In view, namely, of these results of the modern investigation of tubercle, question naturally arises whether analogous investigation of *Cancer* might not be equally successful. The analogy between the two sorts of disease must of course not be overstrained, nor be construed into any prejudgment of facts; but subject to this condition it will, I think, be generally admitted that cancer and tubercle are morbid processes so nearly parallel as probably to throw light on one another, and that methods of investigation which have led to an immensely improved knowledge of the one disease can hardly not lead to instructive results concerning the other. Careful consideration has therefore been given to the possibility of investigating more exactly than hitherto the chronic self-propagative process which is at the root of the diseases called cancerous; and a first preparatory step under your Lordships for the purpose of such an investigation is represented in the fourth of the annexed papers. In it, namely, is the statement of an interesting study which Dr. Creighton has made, and of which the results are there given, with regard to the earlier signs of cancerous infection in the ultimate anatomical elements of the secondarily infected organs.

The fifth of the annexed papers belongs to another sphere of study than the four preceding. It contains, so far as yet ripe for publication, the results of a very important and very laborious research, on which Dr. Thudichum has been engaged for more than two years, in introduction to the *Chemical Pathology of the Nervous System*. During the years 1870–2, Dr. Thudichum, in accordance with the general scheme of work which I explained in my 12th Report, had been investigating the chemistry of typhus; but after following as far as then seemed possible the chemical phenomena of that disease, had found that the results of his work could not properly be deemed more than provisional, and that, under the circumstances as they then stood, direct attainment of final results could not be expected. The difficulty was of a sort to which I have already adverted: it consisted in the want of normal chemical standards by which to measure the morbid declensions in typhus. Especially a leading fact in typhus, one which may be in intimate relation to the killing-power of the disease, and which it is on all accounts necessary to have as completely as possible understood, is the fact of the action on the nervous system; and clearly no true chemical knowledge of that morbid action would be possible, till greatly improved knowledge of the normal brain-chemistry should be

supplied. Accordingly this task was taken in hand; and of course not with exclusive reference to the one disease which gave immediate occasion to it, but in the hope of eventually obtaining results which should be applicable to all cerebral pathology. I need hardly observe that a research of such interest—an endeavour so to unfold the very complex chemistry of the normal brain as to make the abnormal processes chemically intelligible, must, as regards the interest and importance of its object, rank highly among the exact studies by which physiology hopes to give light to Medicine; but I would particularly note that while certainly it is among the most interesting and important of such endeavours, so it certainly must be counted among the most difficult; and I therefore refer with particular satisfaction to the very remarkable evidences of success which Dr. Thudichum is already able to show.

In addition to bringing before your Lordships the accompanying complete papers, I am able to state that much other and equally important work is at present in progress. Especially I may mention that Dr. Sanderson, who for the last three years has been continuously engaged in studies of the infective processes of common fever and common inflammation, will, I believe, early next year have an instalment of valuable results ready for publication with regard to these investigations*; and that Dr. Klein, who has recently been investigating the minute anatomy of enteric fever, and seems already to have succeeded in identifying for the first time the contagium-particles of that extremely important disease, will also, I believe, early next year have his results in this matter sufficiently elaborated for publication.

In closing my present Report, and with the interest which I must of course feel in whatever tends to strengthen the scientific resources of the Medical Profession, I would beg leave respectfully to congratulate your Lordships on the progress of this work which is advancing under your authority, and to express the gratification with which from time to time I find myself privileged to bring its results before you. Equally to your Lordships who have instituted the work, and to the men of science who under your Lordships are instrumental in conducting it, the reflection must, I think, be satisfactory, that, so far as the Investigations fulfil their primary aim of giving aid and

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* Here I may note that two years ago, in the interval between my two series of reports, Dr. Sanderson reported to me some first results which he had then obtained in regard of the infective products of inflammation; and that with their Lordships' sanction (in order not to delay scientific publication of those results) his paper was communicated to the Royal Medical and Chirurgical Society, who published it in the 56th volume of their Transactions. At Dr. Sanderson's suggestion I do not now annex that paper in its original form, but leave its matter to be incorporated by him in a future more comprehensive report.

stimulus to the growth of Medical Science in this one country, their success is contributory to knowledges which are of universal human concern, and which it has therefore ever been the aspiration and the pride of each civilized people to augment for the common good of mankind.

I have the honor to be,
My Lords,
Your obedient servant,
JOHN SIMON.

Medical Department;
July 30th, 1874.

APPENDIX.

On Pathology of the Infective Processes, by Dr. Burdon Sanderson.

No. 1.—Report on Recent Researches on the Pathology of the Infective Processes, by J. Burdon Sanderson.

Since the publication of my former contribution on this subject,* it has engaged a very large share of the attention of scientific pathologists in all parts of the world. As some of the many investigations which have been made have led to results of great importance, I propose to give an account of them. Before doing so, however, it is probably desirable to recapitulate very shortly the conclusions formerly arrived at.

The paper to which I have referred was divided into two parts; in the first an attempt was made to support the position which had then been recently advanced by my friend Professor Chauveau, that in all diseases communicable from person to person, whether by direct or indirect contagion, the infecting agent or *contagium* consists of particles of extreme minuteness, with respect to which it can be asserted that the material of which they are composed is *not* soluble in animal liquids, that it is *not* volatile at ordinary temperatures, and that it possesses a specific gravity very slightly different from that of the liquid in which the particles are suspended.

This conclusion, which was expressed in the sentence, "All contagia are probably particulate," has now, either in the same terms, or in others equivalent, been very generally accepted by pathologists. It was not understood to carry with it any meaning beyond that which is conveyed by the words as interpreted in their strictest sense, and left the question of the form of the hypothetical particles, as well as that of their origin and destiny, entirely open for future investigation. In support of it I set forth the results of Chauveau's now well-known experiments relating to the contagious products of sheep-pox, glanders, variola, and vaccine, many of which I had shortly before had the opportunity of witnessing at Lyons. Those of them which related to vaccine I repeated, modifying them in such a way as to give them the utmost obtainable exactness.

In the second part of the same paper I pursued the subject in an entirely different direction. Starting from the proposition already referred to, that in all probability contagia are particulate, and that the particles are possessed of the properties I had assigned to them, I endeavoured to show that this assumption, when applied to the so-called specific diseases, almost necessarily carried with it the admission of the doctrine of *contagium vivum*, the facts relating to the propagation of contagious diseases through the atmosphere being of such a nature, that supposing such propagation to consist in the conveyance from the diseased to the healthy body of the infective particles, those particles must enjoy endowments not known to exist otherwise than in association with life and organisation.

In connexion with this subject I gave an account of the then recently published researches of Professor Hallier, of Jena, researches undertaken in the hope of demonstrating the identity between the specificity of disease and that of organic forms. As it would have been impossible to have examined into the whole mass of investigations undertaken in this field by that indefatigable mycologist, I confined myself to a careful

* "On the Intimate Pathology of Contagion. Thirteenth Report of the Medical Officer of the Privy Council."

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analysis of the experimental demonstration he professed to give with respect to two important contagia (viz., those of cholera and sheep-pox), of the existence of a definite and constant relation between the human or animal disease on the one hand, and a corresponding parasitic disease of plants used as food on the other. As regards the connexion of cholera with the parasitic disease of the rice plant, supposed by Hallier to be prevalent in the rice-growing districts of Bengal, I showed that there was not even *primâ facie* evidence in support of the author's theory. I also showed that his supposition as to the dependence of sheep-pox on a specific disease of the grass on which the affected animals are pastured, had no foundation.

The following papers, in which I propose to give an account of the present state of our knowledge as to the pathology of the infective processes in erysipelas, splenic fever, diphtheria, and relapsing fever, are intended to form a sequel to my former Report.

There are two relations in which the life of the lowest plants may be supposed to stand to the processes of disease; the one is a relation between *specific* diseases and specific organic vegetable forms; the other between what may be called the *common* processes of disease and those elementary organisms often spoken of as bacteria, which spring up and thrive as if spontaneously, wherever moisture and nitrogen in an available state of combination are present.

These two relations are entirely distinct from each other. They involve different questions and require different modes of investigation. I therefore propose to divide the account to be given in the following pages of some of the most important recent researches relating to the vegetative phenomena of disease, into two parts; the first relating to those diseased processes, mostly of inflammatory origin, in which the ordinary microphytes, associated with the septic transformation of nitrogenous matter, appear to play an important part; the second relating to one or two instances in which the search for botanical characteristics appears to have been successful, the specificity of the disease being represented by a vegetation of recognisable peculiarities of form and development.

Part I.

Nomenclature of septic microphytes.

The air we breathe with its particles of dust, and the water we drink, whether in the ordinary sense pure or impure, contain organisms of extreme minuteness and simplicity of form, which are now commonly spoken of as bacteria. For these organisms, or rather for the group of organic forms which they represent, I proposed in my former paper the term "microzymes," the only name by which they were then and are still known to naturalists (*Schizomycetes*), being too long for common use. Of the legion of observers who have contributed to the literature of the subject during the last few years, most have used Hallier's word *micrococcus*. The surgical pathologists, on the other hand, have devised words for themselves. Klebs, in his book on gunshot wounds, introduced the term *microsporon septicum*.* Hueter in his studies on surgical fever and other secondary traumatic affections has used the word "monads;"† and lastly Billroth has entitled the massive folio which he has lately published on the same subject, *Coccobacteria septica*.‡

* Klebs, Beiträge zur pathologischen Anatomie der Schusswunden, 4to., pp. 133, Leipzig, 1872.

† Hueter, Ueber die chirurgische Behandlung der Wundfieber bei Schusswunden. Volkmann's klinische Vorträge, No. 22, Leipzig, 1871.—Zur Aetiologie und Therapie der metastasirenden Pyaemien. Deutsche Zeitschr. f. Chirurgie, 1872, p. 91.

‡ Billroth, Untersuchungen über die Vegetationsformen von Coccobacteria septica, fol., pp. 244. Berlin, 1874.

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In the existing confusion of terms, it is probably best to continue to employ those words which express most simply the forms of the things referred to. Micrococci it is convenient to call either by that name or simply spheroids; the words dumb-bell, chain, and colony or zooglœa, may also I think be advantageously retained as preferable to the terms *Diplobacteria, Streptobacteria*, and *Gliabacteria*, which Billroth proposes to substitute for them. In addition to these, the word *mycosis* may be conveniently used to indicate the infiltration of a living tissue with micrococci.

The two diseases of which the names stand at the head of the following sections have been placed together because in each of them the local pathological changes are associated with the development of ordinary micrococci in the affected parts, *i.e.*, with mycosis. Both of them present more or less of the characters of specific contagious diseases; but of neither can it be shown that its specificity (admitting that it is specific) is related to that of the form of vegetation with which the diseased tissues are infested.

DIPHTHERIA.

The term diphtheria, like a great many other names of diseases, is used in two senses. By pathological writers, and especially by surgical pathologists, it is constantly applied to a particular mode of ulceration in which the gradual necrosis of the affected tissue proceeds in such a way as to lead to the formation of a membranous slough.

By nosologists, on the other hand, it is used in its original sense, as the name of a specific contagious sore throat, distinguished from scarlatina by the absence of the eruption, and by its habitual tendency to result in laryngeal croup. It is in the latter sense only that the word can be correctly employed. As, however, the correspondence between the so-called traumatic diphtheritis and the pathological *process* of which the fauces are the seat in contagious sore throat, is more than merely apparent, it is important to take some account of what has been ascertained as to the nature of the surgical affection.

Traumatic affections to which the word diphtheritic is ordinarily applied by surgical writers.

The writers who have principally discussed the relation between surgical diphtheritis and mycosis are Hueter and Billroth. Billroth defines traumatic diphtheritis as fibrinous infiltration,* *i.e.*, a spreading inflammation of the skin chiefly characterised by the induration of the infiltrated part, the stiffness being due to the coagulability of the infiltrating liquid. This he calls Diphtheritis, even when the induration eventually results in the formation of pus or in the gradual restoration of the part to its natural state; in this way he is led to include in his definition cases of erysipelas in which there is much induration or stiffening of the inflamed area. Ulceration or loss of substance is not regarded by Billroth as essential, for although he includes those processes of progressive necrosis beginning from a wound, of which hospital gangrene is the type, under the term diptheritis, he admits their title to be so called, not on the ground of their being ulcerative, but on account of the fibrinous character of the infiltration. As regards all these processes he maintains that the filling of the interstices of the tissue with coagulum always precedes the phagedænic ulceration. Hueter agrees with Billroth in regarding surgical diphtheritis as a non-suppurative acute inflammatory infiltration of the integument spreading from a wound, but would confine the word strictly to processes result-

* Billroth, loc. cit. p. 179.

ing in ulceration or destruction of tissue,* while Billroth would extend its meaning to all acute fibrinous infiltrations, and consequently to many cases of erysipelas.

It is scarcely necessary to state that neither of these definitions identify surgical diphtheria with contagious sore throat; but as regards the relation between the morbid process and the mycosis, the two affections are, as we shall see, remarkably comparable with each other. In both we have to do with a spreading necrosis of a previously infiltrated part, in both the lymphatic system is invaded by micrococci; and the question to be solved is whether the previous infiltration is determined by their presence. As regards surgical diptheritis, we have simply a conflict of observation: both parties admit that the interstitial impletion of the tissue with a granular material is the very first change which occurs. Billroth (grounding his statement, so far as I can make out, on the microscopical examination of a single case of hospital gangrene) holds that the granular material is simply fibrin. Hueter, on the other hand, states that the granules are micrococci, and that the process consists primarily in an invasion of the tissue by these organisms. In support of this he records cases of diphtheritic ulceration in which he investigated the condition of the tissues of the skin at the advancing edge of the infiltration, and consequently at the earliest stage of the process, and found that micrococci could be detected in parts where as yet no structural changes and no other formed elements could be recognised. The question is one of difficulty, not merely because the investigation is of such a nature as to demand the greatest anatomical skill, but because cases affording the required material are fortunately of rare occurrence.

Diphtheria proper, or contagious sore throat.

I now proceed to the consideration of diphtheria as understood by the nosologist. For information as to the etiology, symptoms, and pathology of the disease, I cannot refer to any better source than the papers published in 1860 in the Second Report of the Medical Officer of the Privy Council. The question with which we have to occupy ourselves is that of the nature of the *granular* infiltration of the mucosa and of the tissues immediately subjacent to it, which has been long recognised as the necessary precursor of the loss of substance, both in the fauces and in the larynx. In order to place the reader in a position to judge of this question, I will endeavour to give as clear a summary as I can of what is now known as to the local process.

Summary of the more obvious local changes which have their seat in the mucous membrane of the fauces.

In its beginning the process cannot be distinguished from a common catarrh. A contagious sore throat, like an ordinary angina, takes its start somewhere in that region which from its lying between the nares and larynx, may be regarded as belonging alike to the respiratory and alimentary tract, and consists in redness of the uvula, arches, and tonsils, attended with a greater or less degree of pain or discomfort.

The next change has its seat in the epithelium of the same parts; small greyish white spots appear here and there on the surface of the deeply congested membrane, and are mostly of round or oval contour. This appearance is due to a change in the epithelium to an extent corresponding to the area of each spot or patch. The more superficial layers of that structure are thickened and loosened by being soaked with exudation, to such a degree that the slightest touch is sufficient to detach them. After the detachment of the patch, a surface is left behind which scarcely differs from that which surrounds it, for the deep layer of the epithelium still remains. If the soft white membrane is

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* Hueter, Pilzsporen in den Geweben und im Blut bei Gangraena diphtheritica.—Ueber Diphtheritis. Centralblatt f. d. med.-Wissenchaften, 1868, pp. 177 & 531.

examined microscopically, it is seen that it consists entirely of strata of epithelial scales, which, excepting that they are loosened, and are more or less beset with fine granular matter, present normal characters. So far we have nothing before us which can be said to be distinctive of specific angina, for although it is certainly not usual to see the detachment of the epithelium in continuous patches in other forms of sore throat, yet there is no doubt that it may and does occur to a certain extent frequently, and in so far as this happens there is nothing to distinguish them from diphtheria.

The more important changes which follow, have their seat not in the epithelium, but in the immediately subjacent layers of the mucosa. The peeling of the superficial strata of the epithelium having extended over the whole or a great part of the fauces, and the deep layers being thus denuded, new membranous concretions or sloughs, as they are often called, take the place of those which have been detached. These differ both in appearance and consistence from their predecessors. They possess a brownish or dirty grey colour, and are usually firmer and more resistant. On attempting to remove them, it is found that the purpose can only be accomplished at the expense of the tissue of the mucosa; a raw and bleeding surface is left, which is obviously not epithelial.

Before proceeding to state what has been ascertained as to the nature of some of the finer anatomical changes which give rise to these appearances, it may perhaps be useful to refer very shortly to the normal structure of the mucous membrane of the pharynx in those parts which are the favourite seats of the diphtheritic process. In a vertical section of the mucous membrane of the velum or arches of the palate, it is seen that the deep layer of the epithelium (the *rete Malpighii*) is limited towards the mucosa by a well-defined line, the position of which corresponds to that of the basement membrane of the older anatomists. Underneath this comes a narrow band of apparently homogeneous tissue often called the *membrana propria*. Where the mucosa is papillated, this band limits the outlines of the papillæ; but in the parts in question the papillæ are, at all events in young persons, very little developed. The layer which immediately underlies the propria is seen in section as a very close meshwork of transparent fasciculi, the interspaces of which present various appearances according as they correspond to capillary blood vessels or lymphatic interfascicular channels. Of these the former belong to the extremely abundant vascular network which in injected preparations is seen to lie immediately underneath the *rete Malpighii*, its loops reaching to the very surface of the *membrana propria*, and following all its papillary projections. The interfascicular channels of the mucosa communicate first with the superficial plexus of true lymphatic vessels which lies underneath the fine network of capillaries of the papillary layer, and these with the more deeply placed lymphatics of the sub-mucosa, while in the other direction they lose themselves in the *membrana propria*, which though in ordinary sections apparently structureless, can be shown by appropriate modes of preparation to be permeated by cavities containing living nucleated cells, which communicate with their neighbours in every direction by protoplasmic branches. Continuing our examination downwards, we come lastly to the looser texture of the sub-mucosa, in which, in addition to branches of arteries, veins, and nerves, the mucous glands, when present, are embedded; all these structures being in relation superficially with the mucosa, deeply with the muscles.*

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* See E. Verson, Kehlkopf und Trachea. Stricker's Handbuch der Gewebelehre, vol I. p. 453.

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Finer structural changes. Recent investigations of Nassiloff as to the invasion of the tissue of the mucosa, and impletion of its lymphatic channels with masses of micrococci.

The changes which take place in the mucosa have been recently investigated by Nassiloff,* who finds that in sections prepared from mucous membranes in which the diphtheritic process is in progress, but not too advanced, it is seen not merely that the cells of the *rete Malpighii* have undergone remarkable changes, to which it is not needful to refer, but that in the mucosa the interfascicular channels are occupied with similar material, so that they present themselves as a system of opaque granular tracts which intercommunicate with each other, so as to form an imperfect network embedded in a transparent stratum or ground. Proceeding towards the deeper structures, it is seen that the lymphatics with which these channels communicate are filled with similar material, so that in the deeper layer of the mucosa and in the submucosa these vessels present themselves as round, oval, or oblong areas of granulation. This granular material is not, according to Nassiloff, either fibrin or detritus, but consists mainly of micrococci, so that he considers himself justified in regarding the changes which occur in the mucous membrane in faucial diphtheria as probably dependent on the occupation of the channels of absorption by masses of vegetation. As yet nothing has been said of the diphtheritic process as it presents itself in the air passages. In the larynx and trachea its characters differ so strikingly from those met with in the fauces and pharynx, that the most attentive observers, whose means of investigation have been limited to the use of the scalpel, have been led to regard the laryngeal croup as a complication of the faucial angina, not as a continuation of the same process. So far as regards the changes in the epithelium, it would not be difficult to show that the contrast may be attributed to the structural difference between the respiratory and alimentary mucous membranes.

Structural changes which have their seat in the trachea and larynx.

As regards the changes in the mucosa and deeper parts, there appears to be no ground for making any distinction between the mucous membrane of the air passages and that of the fauces. The author already referred to has shown that the micrococcus infiltration can be traced both in the larynx and nares, not merely to the lymphatics of the submucosa, but to the deeper structures—in the former to the cartilaginous tissue, and in the latter to the bony tissue with which it is in relation.

I have already indicated that the micrococci which are found in the diseased tissues in diphtheria cannot be regarded as the generators of the specific contagium (supposing such to exist), the obvious reasons being, first, that the micrococci themselves possess no specific characters, and secondly, that a mycosis of the same kind as that which is associated with diphtheria, occurs in similar connection with other morbid processes which are certainly not specific. There is, nevertheless, another question relating to the subject which still remains open. However certain it may be that they neither embody nor produce any specific contagium, there is still a sense in which they may be pathogenic. The fact that they are present in the earliest stages of the diphtheritic process, and that they find their way even to the extreme limits of the diseased area, would not, even if confirmed by a much larger number of observations than have yet been recorded, be adequate to prove that they are the exciting causes of the subsequent changes. The question is one which can only be answered by experiment, and I now propose to give an account of some efforts which have been made in this direction.

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* Nassiloff, Ueber die Diphtheritis. Virchow's Archiv, vol. L., p. 551. See also on the same subject, Oertel, Experimentelle Untersuchungen über Diphtherie. Deutsches Archiv, vol. VIII., p. 3.

Experimental propagation of the diphtheritic process in animals.

Of the various attempts that have been made to propagate the diphtheritic process in the tissues of healthy animals, almost all have been undertaken in the hope of communicating the disease. I am not indeed certain that any of the experimenters have kept in mind in their investigations the distinction just referred to, between the property of communicating a specific disease, *e. g.* Diphtheria with its sequelæ, in its entirety, and that of merely ingrafting by inoculation, a particular local process.

Some of these experiments have consisted in inserting diphtheritic material in the tissue of the cornea by puncture, others in injecting it subcutaneously,* and others in introducing concretions into the trachea or larynx.† As the most important results have been obtained by the first of these methods, I propose to refer to these exclusively.

There are several reasons why the cornea is preferable to any other tissue for experiments on the propagation of mycosis. Its tissue is better known histologically than any other, and it is closely related in structure to those which are chiefly liable to be the seat of mycoses elsewhere, viz., the superficial layer of the cutis, and the *membrana propria* of the mucous membranes. In addition to this it is the structure in which the phenomena of reaction against injury—those of tissue-germination, and corpuscular infiltration—have been studied with most care.

Artificial production of mycosis of the cornea by inoculation.

The earliest experiments were, I believe, those made by Nassiloff ‡ at Professor von Recklinghausen's suggestion in 1869. His method consisted in simply puncturing the cornea of a rabbit with a needle charged with diphtheritic concretion. The injury gave rise to some hyperæmia of the conjunctiva with purulent discharge, which after two or three days subsided, leaving the cornea of a yellowish colour. On microscopic examination this appearance was found to be due to the impletion of the lymphatic canaliculi with micrococci. In one of the experiments this was accompanied by corpuscular infiltration of the peripheral part of the cornea, the white opacity due to this cause being distinguishable even to the naked eye from the brownish yellow tinge which indicated the mycosis. In these experiments the material was derived in one instance from the pharynx of a diphtheritic child, in the other from a case of hospital gangrene. In both, the material appeared to consist entirely of micrococci.

The next experiments were those of Professor Eberth, of Zurich.§ The material was also derived from faucial diphtheritis. The inoculation was performed by making a number of minute punctures in the cornea, and then introducing the fresh diphtheritic concretion into the conjunctival cavity, care being taken to employ instruments that had never before been used. At the same time the opposite cornea was punctured in the same manner without introducing any infecting material, in order to distinguish the merely traumatic results from those due to the contamination.

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* The most important experiments as to the communicability of the diphtheritic process to animals by subcutaneous injection are those of Trendelenburg—Ueber die Contagiosität und locale Natur der Diphtheritis. Archiv f. klin. Chir., vol. x., p. 720.

† The method of introducing concretions into the larynx was employed by Letzerich and Oertel. Both of these experimenters succeeded in producing in rabbits a disease which corresponded with diphtheria as well in its local as in its general manifestations. As, however, the significance of the results obtained by them seems to admit of question, I think it undesirable to refer to them in the text, but have added a note on the subject at the end of this paper.

‡ Nassiloff, loc. cit.

§ Eberth, Zur Kenntniss der bacteritischen Mycosen. Leipzig, 1872, p. 6.

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When this method was used it was found that in the uninfected eye the reaction was confined to the appearance of a slight opacity round each prick, which in a couple of days had disappeared. The other in 24 hours was in a state of advanced suppurative inflammation. On examining the cornea with a low power (after the animal had been killed), each puncture presented itself as a greyish brown patch of stellate contour on the anterior surface of the organ. At a deeper level in the corneal tissue, streaks of the same colour were seen stretching from the seat of puncture and intersecting each other in various directions, corresponding to those of the lymphatic canaliculi. On making sections of the organ and examining them with a higher power, the yellow granular substance was found to consist entirely of micrococci.

From these experiments Eberth concludes that the invasion of a tissue by micrococci may result in its disintegration either by the directly destructive action of the organisms themselves, or by the inflammatory reaction to which they give rise, but that in either case they are the primary agents, the efficient causes, by the operation of which the process originates.

Both Eberth and Nassiloff made comparative experiments with ordinary putrid liquids, for the purpose of ascertaining whether results of the same kind as those described above could be thus obtained. These were for the most part negative, showing apparently that micrococci bred or nourished in tissues actually undergoing diphtheritic processes acquired thereby such a habit as fitted them for colonising in a new tissue more readily than others. Subsequently, however, Eberth * published other experiments in which he showed that corneal mycosis could be brought about by any injury of which the mechanical conditions were favourable to contamination from the ordinary sources. Thus, for example, he found that even in corneas inflamed by a thread seton, a certain degree of micrococcus infiltration could be made out in the neighbourhood of the wound. He also found that in the affection of the cornea produced by section of the fifth nerve the disintegrative process was in its origin in great measure mycotic.

As, however, the question still appeared to be doubtful, a new and very extended series of experiments was undertaken by Dr. Dolschenkow in the pathological laboratory of Professor von Recklinghausen, at Strasburg.† The materials used in these experiments were not specific. In some the white or brownish smeary *enduit*, consisting entirely of micrococci and bacteria, which covers putrescent muscle when kept in moist air, was used, in others the scum from putrescent animal liquids. Each inoculation was made by a single puncture in the upper half of the cornea. 112 experiments were made, of which 29 were entirely successful, and 31 partially so. In the remainder the results were negative. The effects were as follows:—After 12 hours a slightly prominent opacity appeared at the seat of each inoculation, the conjunctiva being hyperæmic and slightly œdematous. Six hours later the opacity had increased to the size of a hemp seed; in its centre was a small ulcer, around which the cornea was yellowish, the rest of it beginning to show grey opalescence. At the end of 24 hours the ulcer had increased to the size of a hemp seed and had become deeper, the epithelium of the cornea was detached and the general opalescence had

* Eberth, Die diphtheritischen Processe. Keratitis nach Trigeminusdurchschneidung. Centralblatt, 1873, pp. 113 and 502.

† Dolschenkow, Impfung faulender Substanzen auf Kaninchenhornhaut; Centralblatt, 1873, p. 655.

passed into opacity. There was already hypopion $\frac{1}{20}''$ deep, and the cavity of the conjunctiva was full of purulent liquid. During the next two days the ulceration of the cornea progressed towards its margin, and eventually, about the end of the third day, perforation usually took place, the conjunctival inflammation having already subsided.

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Most of the animals appear to have been killed for microscopical examination about the second day, but there is a want of precise statement upon this point. In each case sections of the prepared cornea made parallel to the ulcerated surface, and at different distances from it, were investigated. Nearest the surface the canaliculi were found to be so occupied with corpuscles and detritus that the extent to which micrococci were present was difficult to determine. In the succeeding sections the corpuscular infiltration was less, and diminished more and more as the deeper strata were reached. Here, although the tissue was perfectly transparent, there were numerous canaliculi which were filled with micrococci to a breadth of $\frac{1}{8000}''$. They could indeed be traced as far as Descemet's membrane, and it was in these deepest layers that the channels showed themselves most beautifully as long slender streaks which exhibited a granular appearance and distinctly brown colour. In addition to the micrococci contained in the canaliculi, isolated microphytes were scattered in the ground substance, most of them following in their distribution the course of the fibrillation. In form the greater number of these were rod-like. The author was unable to discover any micrococci either in the other tissues of the eye, in the pus of the hypopion, or elsewhere in the bodies of the animals.

It was stated above that 46 per cent. of the experiments failed. These failures were attributed by Dr. Dolschenkow in some instances to defective manipulation. Of the remainder a few could only be accounted for as resulting from insusceptibility on the part of the animals used; but the greater number appeared to be dependent on the nature or condition of the infecting material. With reference to this point it was found first, that no result was obtained unless the micrococci were introduced in mass, and secondly, that it was only at an early stage of their development, that is of the putrefactive process, that they possessed a sufficient infective intensity to insure positive results. In comparing these experiments with those of Eberth in which the material employed was of diphtheritic or at all events of pathological origin, it is to be noted that the quantity used by the latter was very much smaller, so that the results, even if they weaken Eberth's inference as to the greater infectiveness of his diphtheritic micrococci, cannot be said to dispose of it altogether. It must be admitted that the subject is still in some obscurity. It is, however, of moment to have learnt that forms of micrococci exist which possess the power of colonizing in living tissues, and thereby inducing a variety of inflammation which is distinguished from others by its tendency to result in disintegration, and that this faculty of originating disintegrative inflammation is possessed by them independently, and can be exercised without the concurrence of any previously existing morbid process.

Erysipelas.

Definition of the term erysipelas.

In the following paragraphs the word erysipelas is understood in its stricter rather than in its wider sense. The most obvious character by which an erysipelas is distinguished from any other inflammation of the skin, as for example that which is present in a burn of sufficient intensity to produce vesication, consists in the fact that it originates from a focus of infection. The way in which it spreads from such a focus over the

surface of the skin may be aptly compared to that in which the process of combustion gradually extends over a sheet of brown paper from any point which has been set fire to. As a rule the infective focus of an erysipelas is a wound, excoriation, or other breach of surface. Sometimes it happens that no traumatic cause can be discovered, but even here it is not the less evident from the form and characters which the patch of redness presents at its first appearance, that the spreading inflammatory process has started either from one centre of origin or from several neighbouring centres at the same time. In either case it is equally plain that a local infection has occurred, *i.e.*, that a contagium has been inserted or otherwise come into existence in the tissue of the affected part.

Summary of the more obvious local phenomena.

Before proceeding to discuss the anatomy of the process of erysipelas it may be well to refer very shortly to some of the obvious changes which the skin undergoes. The red patch with which erysipelas begins, is always limited by a sharply defined contour line, which may be termed the line of extension. Beyond this line, that is further from the centre of origin, the skin is apparently normal; immediately within, it is not only redder than it is over the rest of the affected surface, but turgid from infiltration of interstitial liquid or tissue-juice; this turgidity gives rise to a raised border readily felt by the finger in passing from the healthy to the affected surface. A spreading inflammation of the skin of which the order of extension has the characters just described must be regarded as an erysipelas whether it occurs in man or the lower animals, whether it is induced or of apparently spontaneous origin. It is remarkable that up to a comparatively recent period the finer anatomical changes that occur in the skin in erysipelas were not investigated; the intense redness appeared to be so completely explained by the injection and distension of the blood vessels of the cutis, and the swelling by the soaking of its tissue with serous fluid, that these two changes, viz., congestion and infiltration, were taken as the only elements of the process; for it appeared to be very improbable that an inflammation which does not as a rule affect the same part for more than two or three days, and when it disappears, leaves no visible trace behind it, should be attended with any structural alteration in the tissues.

Structural changes.

The first serious investigation of the histological changes which occur in erysipelas was made six years ago by Volkmann and Steudener,* the material being derived from cases which occurred in the course of an outbreak of the disease at Halle. The principal difficulty in this investigation was, as may be readily supposed, that of obtaining specimens of skin for microscopical examination in which the process was still progressive; for in such cases of erysipelas as result in death, it usually happens that the extension ceases entirely some time before the fatal issue. In three instances, however, out of sixty examined, the process was still extending. The changes described by Volkmann and Steudener as they present themselves in vertical sections of erysipelatous skin in the stage of progress are as follows:—In the superficial layer of the corium the most prominent feature is the vascular injection, which is so intense that the papillæ look as if they consisted entirely of loops of distended capillaries. In addition to this, the vessels are seen to be surrounded by cells in great numbers which present the well-known characters of the colourless corpuscles of the blood; in the deeper layers of the cutis these are so numerous that they form a continuous sheathing to each vessel,

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* Volkmann und Steudener, Zur pathologischen Anatomie des Erysipelas. Cenralblatt, 1868, p. 561.

these sheaths communicating with each other by tracts of corpuscles, of which the arrangement corresponds to that of the network of inter-fascicular spaces of the connective tissue.

It was formerly supposed that erysipelas proper could be distinguished from purulent subcutaneous cellulitis not merely by the absence of suppuration, but by the circumstance that in the former disease the effusion or infiltration has its exclusive seat in the cutis. Volkmann and Steudener's investigations show that neither of these distinctions has any sufficient foundation ; for there is no difference between the two diseases, either as regards the characters of the individual migratory corpuscles, or as to their proportionate prevalence in the different layers of the integument. In erysipelas, as in other forms of inflammation of the skin, the chief seat of corpuscular infiltration is not the cutis but the cellular tissue; for whereas in the former, particularly in its superficial layers, the number of migratory corpuscles is relatively very small, the tracts of infiltration that surround the vessels of the subcutaneous cellular tissue, as well as those which follow the course of the connective tissue bundles and surround the groups of fat cells, are often of such a size that a single tract may occupy the whole field of the microscope, and can be readily distinguished by the naked eye in vertical sections as a streak of white opacity. In the subcutaneous adipose tissue the corpuscles are seen not only to surround the masses, but to penetrate between the individual fat cells, following here as elewhere the distribution of the vascular system. As soon as the process begins to recede and the skin regains its natural colour, or assumes the peculiar yellow tinge usually seen after erysipelas, the emigrated cells undergo rapid degeneration, so that after a day or less, all that remains of them is granular detritus. This process goes on so speedily that in the course of three or four days no trace of what has occurred can be detected, the *restitutio ad integrum* being as complete when scrutinised by the aid of the microscope as it appears to be to the naked eye.

Bearing of the preceding facts on the pathology of erysipelas.

The observations of Volkmann and Steudener, although they are of great value as contributions to the anatomy of erysipelas, do not materially aid the comprehension of those attributes of the process from which it derives its right to be regarded as infective ; for the structural changes described by them for the first time, afford no better criterion than we possessed before for distinguishing the erysipelatous from other forms of inflammation ; for if, as Volkmann justly remarks, we were to produce an inflammation of the skin by the application of strong solution of iodine or otherwise, we should find the vascular congestion, the corpuscular infiltration, and the other finer textural changes presenting just the same characters as in erysipelas ; so that if we were to depend upon the aid of the microscope we should find it even more difficult to discriminate between the one process and the other than when we relied on the mere naked eye appearances. In relation to our inquiry, these results are chiefly of value in so far as they enable us to get rid of previously existing anatomical misconceptions. So long as it was supposed that the erysipelatous inflammation had, or at all events might have, a special anatomy of its own, the attention of pathologists was too apt to be drawn from the study of the process itself to structural changes in the tissues affected. Here, as in other instances in which we know what is going on only by its effects, the observer must guard himself against allowing his attention to be so engrossed with the characteristics of a process that the process itself is concealed from him. It is evident that in every erysipelas, changes must have taken place in the tissue at a period antecedent to the corpuscular infiltration, and even to the effusion. The question is, do these early changes leave any

trace behind them? If such traces exist, they will be found not in the inflamed skin but in the skin about to become inflamed; not at the swollen line of extension but beyond it.

Two attempts have lately been made to elucidate this question; one of them by Dr. Orth, of the Pathological Institute in Berlin; the other by Dr. Lukomsky, under the direction of Professor v. Recklinghausen, of Strasburg. Of the first of these researches I propose to give a short abstract; the second is of such importance and value in relation to our inquiry that it seems desirable to reproduce the whole of the author's observations and experiments in a condensed form.

Dr. Orth's experimental researches on erysipelas.

The purpose of Dr. Orth's inquiry* was to ascertain, first, whether it is possible to communicate erysipelas to the lower animals by inoculation of the products of erysipelatous inflammation, and secondly, whether the specific activity of such products depends upon the living organisms (micrococci, bacteria, &c.) they contain. With reference to the first question, a large number of experiments were made, which showed that when the liquid of an erysipelatous bulla or other inflammatory product, is injected subcutaneously in the backs of rabbits, a spreading inflammation is produced which corresponds in every important respect with erysipelas. The redness and swelling extended from the wound over the whole trunk and extremities, the temperature at the same time rising to 106°–107° Fahr. The redness was most intense in the immediate neighbourhood of the line of extension, along which it was limited by a well-defined swollen margin; in the other direction it faded off gradually into the yellow tinge which prevailed generally where the inflammation had already subsided. On dissection, the red parts exhibited marked hyperæmia of the vessels of the skin, along with œdema and loss of transparency of the subcutaneous cellular tissue; in some cases there were small abscesses under the skin, in others none. On microscopical examination the infiltrating liquid of the swollen parts contained an enormous number of bacteria. The anatomical changes in the cutis corresponded with those of erysipelas described by Volkmann and Steudener.

In a second series of researches a cultivation liquid prepared after Cohn's formula, which had been inoculated by the addition of a few drops of the morbid product above referred to, so as to determine the development of bacteria, presumed to be identical with those contained in the added liquid, was used for inoculation in the same way as before. The result was very similar to that obtained in the previous experiments.†

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* Orth, Untersuchungen über Erysipel. Archiv. f. experimentelle Pathologie, Vol. I. p. 81.

† It may probably be admitted that in the experiments above related the disease produced was really erysipelas; but clearly they do not prove or render probable the conclusion derived from them by Dr. Orth, that the material used for the inoculation, owed its activity to a specific contagium peculiar to that disease. In my previous investigations relating to secondary inflammation, I had repeatedly occasion to observe that the subcutaneous injection of irritant liquids gave rise to erysipelatous inflammation, even though the most scrupulous care was taken to avoid the contamination of the liquid used with any infective product whatever; and I have no doubt that if Dr. Orth had guarded himself against error by making comparative experiments, either with chemical irritants of sufficient intensity, such as ammonia, or with products derived from other kinds of infective inflammation, he would have obtained the same results. It may be further noticed that the experiments lose much of their value from the intensity of the effects produced. The rapidity with which the *status quo* is restored after the cessation of the erysipelatous process, is as characteristic of it as the rapidity of its invasion, so that in any attempt to imitate it, the dose of the agent employed ought to be as small as possible. In some of Orth's experiments the results rather presented the appearance of purulent œdema of the subcutaneous tissue than of erysipelas proper.

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Dr. Lukomsky's researches.

Clinical and pathological observations.

Dr. Lukomsky's paper* consists of two parts: the first is a record of anatomical investigations made partly by Professor von Recklinghausen, partly by the author; the second relates to experiments made for the purpose of testing the identity of induced erysipelas with the natural disease, and obtaining material for conclusions as to the nature of the infective agent.

Case 1.—Sophia G., æt. 60, affected with heart disease, was transferred from a medical to a surgical ward (March 23), on account of erysipelas of the face of two or three days' duration, which had been preceded by rigors. The disease ran a rapid course and terminated fatally on the third day after the patient's admission (March 26). There was no trace of previous injury of the skin.

Pathological appearances:† March 27.—Fat pretty abundant. Bluish reddening of neck and upper part of chest, whence streaks extend to the back. Slight swelling of right side of upper lip and nose. Excoriations and brown crusts on lips. Swelling of eyelids, particularly left. Much incrustation about inner angle of right eye; tissue soft, collapsed; fluid discharge from crusts. Marked chemosis of right eye; mucous secretion in conjunctival cavity. Excoriations under skin; commencing vesiculation on neck, where subcutaneous tissue is soft and infiltrated with pus. The purulent infiltration extends into the intermuscular connective tissue of the neck, but not beneath the pectoral muscles. Tissue of anterior mediastinum infiltrated with reddish but not purulent liquid. Clear brownish fluid in both pleuræ; similar fluid containing fibrinous flocculi in pericardium. [The heart was enlarged, and exhibited the signs of old valvular disease. Lungs normal, with the exception of slight œdema of right lung.] Œdematous infiltration and redness of fauces, base of tongue, and left aryteno-epiglottidean fold. Left kidney small; its surface granular, without ecchymoses; a few white streaks and specks are observed in the medullary cones, which, however, are not distinctly purulent. [No other morbid appearance of importance.]

Underneath the crusts of dried-up vesicles on the neck, the whole of the cutis and subcutaneous tissue is infiltrated with fluid containing cells. . . . The interstices of the cellular tissue fasciculi of the cutis present in section irregular stellate figures, which are most numerous along the course of vessels. In the subcutaneous tissue the cells are in larger aggregations, so as to form purulent foci, which are connected together by tracts of granular deposit consisting of coagulated fibrin. In the skin of the chest the infiltration was slighter, but here some lymphatic vessels were observed which were filled with micrococci, while in other parts lymphatic cavities occurred in which there were collections of the same organisms. At the edge of the affected part, where the infiltration was very slight, several lymph vessels, recognisable by their varicose contours and the jagged form of their processes, were completely plugged with micrococci. These organisms could occasionally be discovered in the lymphatics of the apparently healthy skin, even as much as nine lines beyond the margin of extension. In the subcutaneous tissue of the chest, commencing cellular infiltration could be made out.

In the skin of the head the inflammatory process was obviously in

* Lukomsky, Untersuchungen über Erysipel. Virchow's Archiv., Vol. LX., 1874, p. 418.

† The pathological observations, all of which are by Prof. von Recklinghausen, are for the most part translated. Where it has been thought necessary to abridge them, the abridged portions have been enclosed in brackets.

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recession, the lymph cavities being filled with small round cells, in process of fatty transformation, and free fat granules. The "streaks" in the kidneys were found to be due to corpuscular infiltration; in the infiltrated parts the blood vessels were plugged with micrococci, in the manner first described by v. Recklinghausen in 1871.* Capillaries filled with micrococci also existed in the muscular tissue of the heart, which, however, were not associated with inflammatory changes.

Case 2.—Dorothea H., æt. 43, was admitted on account of a cystosarcoma of the right breast, which was excised on March 6. On the 8th erysipelatous redness appeared at the edge of the wound, which by the 10th had extended to the left nipple, and thence to the back. Intense fever, unconsciousness, with lividity of affected parts, resulted in death on the 13th without further extension of the erysipelas.

Pathological appearances, March 14.—Surface of wound dry. Dry excoriated patches on the skin of the chest. Skin of axillary cavity reddened hæmorrhagically, and excoriated in places, where it is of doughy consistence. On the left side of the chest the epidermis is peeled off, and here and there vesiculated. . . . [No noteworthy appearances presented themselves in the other viscera.]

Anatomical investigation of skin.—Surface of wound covered with a thin layer of broken-up pus corpuscles and granular detritus. . . Purulent infiltration of the subjacent tissues, with dilated blood vessels and extravasations here and there. . . . Edge of wound exhibits a brownish border a line in width, the cut surface of which is remarkably smooth and shiny. In this part it was found that the cellular tissue fasciculi had a glass-like appearance and swelled very little in acetic acid, and that the blood vessels were dilated with blood in which the corpuscles could not be distinguished. The malpighian layer of the epithelium was altered so as to resemble the *stratum corneum*, the processes between the papillæ being transformed into slender parallel streaks, and the papillæ themselves containing vessels in the same condition as those last mentioned. Between this and the inflamed part the transition was rather abrupt, the cells of the malpighian layer of the intermediate part being more distinct than at the very edge of the wound, but still small and granular. Along the line of commencing inflammation there were dilatation of the vessels and abundant corpuscular infiltration, the cells of the rete being swollen, and some of them exhibiting vacuolation, while the papillary blood vessels were so dilated that they occupied almost the whole width of the papillæ. . . .

[The most important changes were observed in the deeper layers of the subcutaneous tissue.] Almost immediately on the surface of the muscles, micrococci existed in vast numbers, forming extensive colonies of the most various forms—round, oval, cylindrical, or stellate. In some places portions of large lymphatic vessels occurred, completely filled with micrococci, the largest colonies being always found in natural cavities, which were also probably lymphatics. In the neighbourhood of the colonies numerous bodies of stellate form, consisting of micrococci, occurred, which were united by their processes so as to constitute a network. The colonies themselves were most numerous in the tracts of connective tissue between fat masses; but the adipose tissue itself was also occasionally obscured by scattered micrococci. Notwithstanding this deposit of micrococci the tissue was free from corpuscular infiltration. [These facts were observed only in the immediate neighbourhood (to a distance of $2\frac{1}{2}''$) of the wound; beyond this the skin was not examined.]

* v. Recklinghausen, Würzburger Verhandlungen, Jan. 10, 1871.

Case 3.—Mathilde L., æt. 15, admitted into hospital for hip-joint disease. Three weeks after the opening of a large abscess, erysipelas commenced (May 18) at the edge of the wound which had not completely united, rapidly spreading over the whole body, with the exception of the head and one forearm. Intense fever, with vomiting and diarrhœa, supervened, terminating fatally June 7, the progress of the erysipelas having ceased two days previously.

Pathological appearances, June 9.—Body emaciated and pale. Skin of lower limbs covered with flakes, under which it is still reddened; some redness of right arm. An incision 9‴ long in upper third of inner aspect of leg. Purulent infiltration of integument of neck; inner half of left clavicle bare of periosteum and bathed in pus. Sterno-clavicular joint opened. Cellular tissue of the anterior mediastinum infiltrated with pus. Both pleuræ contain muddy liquid, with purulent fibrinous deposits. Lungs here and there adherent. Pericardium contains a little muddy liquid; heart small . . . . . ; its internal surface stained. [No important pathological changes in other viscera, excepting that in a few papillæ of the kidneys there were yellowish streaks, and that the retroperitonæal lymphatic glands were much reddened and swollen and surrounded with purulent infiltration, which extended to the pelvic cavity, and thence through the pelvic wall into the left cotyloid cavity.] Luxation upwards of the head of the right femur. Large quantities of pus outside of the pelvis. Carious kyphosis of the thoracic vertebræ, around which there is an enormous cavity filled with thick yellow pus, containing several bony fragments.

Anatomical investigation of diseased skin.—Excessive corpuscular infiltration of the subcutaneous tissue generally; purulent foci under integument of lower limbs; micrococci occur only occasionally and in small groups in the integument of the legs, the appearances referable to their presence being insignificant. Elsewhere in the integument no micrococci could be discovered. In the lungs, liver, and kidneys (in which last they were found in the streaks above referred to) capillary blood vessels obstructed with micrococci presented themselves repeatedly.

Case 4.—Augustin B., æt. 9, an anæmic child of feeble constitution, was admitted June 18, on account of a swelling in the left axilla, consisting of enlarged lymphatic glands, which was excised on the same day. Erysipelas commenced from the edge of the wound June 21, which soon spread over the chest and back. It then (June 23) receded, the general condition becoming worse, the case terminating on the 24th. Before death an erysipelatous redness appeared on the left arm (which had been previously free).

Pathological appearances, June 26.—[Cavity of wound contains much disintegrated tissue infiltrated with pus. Swelling of integument and peeling of the epidermis of left side of chest. Masses of cheesy infiltrated glands on both sides of neck, extending to ears, many of them containing mortar-like substance. Right pleura contains about 10 ounces of reddish muddy liquid with fibrinous masses, both free and covering the pulmonary surface. Left pleura partly adherent, otherwise in a similar condition to that of the right. Tissue of anterior mediastinum dense, and containing enlarged and degenerated glands. Right costal pleura reddened, especially between the ribs. On the left side the intercostal tissue contains several nodules as large as cherries, which also consist of cheesy substance. Pericardium contains greenish liquid with fibrinous masses, free or attached to the serous surfaces; the membrane itself is thickened, reddened, and externally scattered with ecchymoses.

The right lung exhibits lobular patches of grey consolidation of the lower lobe, which, however, for the most part contains air. Other lobes contain old indurations. Left lung œdematous, otherwise healthy. Bronchial glands enlarged and degenerated and surrounded with dense tissue. Mesenteric glands also enlarged and caseous. Considerable alteration of the solitary follicles, but no ulceration of intestine. No other important lesions.]

Anatomical examination of diseased parts.—From the lower edge of the wound to an extent of several inches, the lymphatics of the skin and their branches were found to be choked with micrococci. This was particularly the case in the two layers of lymph capillaries of the corium, which as is well known lie intermediately between the two networks of blood capillaries. [In the author's drawings the form and arrangement of these networks are well seen. In the superficial layer of lymphatics the channels have varicosities, often jagged processes, which are seen to be continuous with colonies of micrococci, which from their form must be regarded as contained in lymphatic canaliculi (Fig. 2). The lymphatics which lie under the deeper network of blood capillaries of the corium (*stratum internum* of Teichmann) do not present the jagged outline of the others; they run parallel for the most part with the connective tissue bundles and elastic fibres (see Figs. 4 and 5). The drawings illustrate the relations of the vessels of both layers with the blood capillaries, showing particularly as regards the more superficial layer how they occupy the interspaces of the capillary network. At a greater distance than two inches from the wound it was found that the micrococci no longer occupied the lymph vessels, but were met with exclusively in blood capillaries; several loops of such capillaries sometimes occurring together entirely plugged with micrococci. Commonly, however, the plugging did not extend beyond a single branch. In other instances colonies presented themselves at points of bifurcation. In this case the corpuscular infiltration of the affected parts of the skin was only considerable in the deeper layers near the course of vessels. In the subcutaneous tissue it was almost entirely wanting. There was no infiltration with micrococci near the upper margin of the wound.]

Case 5.—Therese S., æt. 60, admitted for a large swelling in the neighbourhood of the left parotid, which was evacuated on June 9 by means of Dieulafoy's aspirator. As on the next day it had again filled, it was laid open by a long incision. It was then found to be a cavernous tumour. On the same day a similar tumour of the breast was excised. Three days afterwards the skin began to redden around the edges of the excision wound; by the 17th erysipelas had spread over the chest, and shortly afterwards extended to the back. On the 23rd the erysipelas subsided, but the general condition became worse, and the patient died on the 27th. Shortly before death there was a new extension of erysipelas in the neighbourhood of the seventh vertebra.

Pathological appearances, June 28.—[Much œdema of the legs; moderate distension of the belly. The cavity of the wound near the parotid contained greyish pus, and the parotid itself was in a state of purulent disintegration. The skin in the neighbourhood of the excision wound is reddened and exhibits peeling of the epidermis. The left pleura contains about a pint of greenish liquid, but there is none in the right. Both the pulmonary and pleural costal surfaces are coated with fibrinous deposits, under which the pleura is reddened in some parts; in others it is adherent. At the lower margin of the left lung there is a gangrenous nodule surrounded by lung tissue in the state of commencing purulent infiltration, as well as smaller foci in other parts of

the lower lobe. The right lung also contains metastatic foci, none of which is as large as a cherry. The other pathological appearances were not important.

The microscopical investigation of the affected skin showed that there was only moderate corpuscular infiltration of the cutis, which did not extend at all to the subcutaneous cellular tissue. Fatty degeneration of the infiltrating cells was already beginning. No micrococci could be observed anywhere in the parts first affected; but in the region in which the erysipelatous process showed itself only a day before death, the lymphatics as well as the canaliculi of the connective tissue were occupied by them, the appearances being the same as in the other cases.]

In four other cases of erysipelas in which the disease was also receding, it was similarly found that there were no micrococci; the cells with which the tissue was still abundantly infiltrated being in a state of fatty degeneration.

Experimental researches.

The purpose of the experimental part of the investigation was, as has already been stated, to determine in how far the apparently erysipelatous inflammation of the skin, which can be produced artificially in rabbits by the introduction of liquids containing septogenic organisms, corresponds anatomically with erysipelas in man. The experiments which were made at the instance of von Recklinghausen were commenced after the completion of the clinical part of the inquiry. They were of two kinds; in some the liquids were injected subcutaneously, in others material containing septic bacteria was applied to wounded surfaces.

Subcutaneous injection of liquids containing micrococci.

1. The contents of a cyst evacuated after death, which had been allowed to stand in ice for 24 hours, were employed. The liquid was of a yellowish red colour, and contained a well-formed gelatinous coagulum. It presented, besides numerous blood corpuscles, micrococci and bacteria in abundance, both scattered and in colonies, which were largely made up of necklaces. There was no trace of putrid odour. A cubic centimeter of this liquid was injected into the skin of the right side of the back of a young rabbit which had been carefully shaved, and some of the coagulum was similarly inserted in the opposite side. The animal died 26 hours after the inoculation. Five hours before death it was collapsed, its temperature having diminished from 104° to 97·7° Fahr.; livid red streaks extended from the seat of injection on the right side to the middle line; on the left side, where the coagulum had been inserted, the redness had spread over the whole left flank and left hind limb; at the middle line the two regions of redness had united, and there was doughy œdema of the integument of the belly posteriorly. On dissection the skin was found to be infiltrated with reddish serous liquid containing innumerable bacteria. Sections of skin hardened in alcohol showed intense vascular injection with numerous extravasations; pus corpuscles occurred sparingly in the skin, abundantly in the subcutaneous liquid. The sections of skin always exhibited the appearance of a "stellate network of micrococcus," that is, a network formed by the confluence of the branches of a number of stellate masses corresponding in arrangement to the lymphatic canaliculi. The author's drawings show lymphatic vessels completely filled with micrococci. In the internal organs, micrococci existed in the muscular tissue of the heart, in the liver, and in the kidneys.

2. After keeping the liquid used in the above experiment for a week, about 12 minims were injected subcutaneously on the left side of the back of a rabbit. Redness began to extend from the wound about eight

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hours after the injection, and gradually spread over the whole of the trunk during the following day. The line of extension was dark red, somewhat hæmorrhagic, and slightly prominent. The animal survived 48 hours. Before death the whole of the affected part acquired a yellowish green tinge. The general appearances found on dissection resembled those described in the previous experiment; the investigation of the skin again showing that the relation between corpuscular infiltration and infiltration with micrococci is the same in the artificial process as in the natural. At the line of extension the cutis was found to be infiltrated both with young cells and micrococci, but two tenths of an inch or less beyond this line, the cells were wanting, the stellate spaces of the lymphatic canalicular system of the cutis being occupied by a network of micrococcus masses of the kind above described, the direct continuity of which with lymphatic vessels also filled with micrococci could be distinctly made out.

3. Two drops of aqueous infusion of muscle of frog were injected subcutaneously in the back of a rabbit. In this case the animal survived eight days—sufficient time to allow of the recession of the inflammation of the skin, which was at first very extensive. The affected parts were of a yellowish colour, the infiltration of the subcutaneous tissue had disappeared, excepting in the foot, where sufficient quantity was obtained for microscopical examination. In this liquid no organisms could be found; in sections of affected skin hardened in alcohol, cells in advanced fatty degeneration and detritus were met with, but no trace of micrococci.

(Experiments 4, 5, and 6 are omitted as being similar to the above.)

Summary of the results of the first series of experiments.

The results of the first series are summed up by the author as follows:—(1.) The previous observation, that by subcutaneous injection of liquids containing micrococci, intense spreading inflammation of the subcutaneous tissues, in which the cutis participates, is confirmed. (2.) In this process the micrococci, multiply rapidly in the tissue, distributing themselves principally in the lymphatic canaliculi and vessels. (3.) This process can be induced by a fluid containing micrococci even when it shows no signs of putrescence (*e.g.*, by a fluid obtained from the living body, in which there could be no question of septic change unless the very presence of these organisms is to be considered itself proof of putrescence). (4.) Fluid from a dead body, if free from micrococci and bacteria, produced only a local effect which had no tendency to spread. The contents of erysipelatous bullæ, if free from micrococci, produce no result.*

Application of material containing Micrococci to wounded surfaces.

7. A wound $\frac{4}{10}''$ square having been made in the back of a rabbit, the coagulum referred to in Experiment 1 was applied to it. After 24 hours the wound was covered with a brownish depressed crust, and surrounded by a swollen margin; redness extended in all directions from it. By the fourth day the redness had reached the left groin, and spread thence over the left thigh and to the right side of the back.

8. A wound of similar size having been made in the left side of the back of a rabbit, a portion of the frog's muscle used in Experiment 3 was applied to it for eight hours, being secured by plaster. At the time it was removed the wound was surrounded by a patch of redness and swelling which extended nearly 3 inches in length and $1\frac{1}{4}''$ in breadth, exhibiting numerous hæmorrhages. The edges of the wound

* The two last statements are founded on negative experiments, of which I omit the details.

were red and swollen, and its surface of a dirty white appearance. In portions of skin around the margin of the wound which were removed at this time and hardened in alcohol, the canaliculi and lymphatic vessels were already filled with micrococci. The animal died on the fourth day; the redness and swelling had extended to the middle line of the belly, where there was an œdematous tumour as large as a hazel nut, which on puncture yielded a reddish liquid containing numerous bacteria. In most parts of the affected skin the corpuscular infiltration was so considerable that the appearances, so far as related to the micrococci, were less distinct.*

12. A portion of putrid flesh three days old was applied in the same way to a superficial wound on the left side of the back of a rabbit. On removing it eight hours after, a patch of redness and swelling, the border of which was sharply defined, extended 1½″ towards the left side of the belly. It was œdematous at the edge, and on puncture yielded a liquid containing, besides leucocytes, bacteria and micrococci. Portions of skin at the edge of the wound removed for microscopic examination, showed the presence of micrococci in the canaliculi. Next morning the animal was killed. The affected skin was infiltrated and its sectional surface reddish; the subcutaneous connective tissue was œdematous. On the surface of the fascia covering the muscles small hæmorrhages were observed which on the right side near the vertebral column were confluent. Between these places and the affected skin the vessels were strongly injected. On subsequent microscopical examination it was found that the tissue was full of extravasated coloured and colourless blood corpuscles; the latter had assumed very various forms and contained refractive granules in great numbers. In some of the capillaries that still contained blood, bacteria could be distinguished in the serum. In sections of skin from the neighbourhood of the wound, appearances similar to those in Experiment 8 were observed. "At the part where the progress had been most rapid there "was still considerable deposit of fibrin which extended somewhat "beyond the margin of redness. In this fibrin micrococci were embedded; "it was so granular that the micrococci could not be made out until "the preparation had been treated with acetic acid and warmed. They "were found in moderate numbers occupying the canaliculi."

Experiments 13, 14, 15 and 16 are omitted.

Summary of the results of the second series of experiments.

From this second series of experiments the author concludes (1), that septic material containing micrococci, when applied to a wound, produces intense local inflammation which rapidly affects the surrounding skin; the spreading disease thus produced corresponds in all its phenomena with erysipelas. (2) In this process the bacteria and micrococci penetrate into the skin by means of the canaliculi and lymphatics. They are to be found in the greatest numbers at the periphery of the inflamed patch, and particularly in that part of it where the process of inflammation is progressing most rapidly. (3) The erysipelas thus produced tends to spread in certain directions more than in others. When the wound was in the middle of the back or near it, the progress of the inflammation was most rapid towards the belly, but more rapid backwards than forwards. This the author thinks may depend on the direction of the bundles of connective tissue, or that of the lymphatic vessels, or on the influence of gravitation, but he is unable to arrive at a definite conclusion on the subject.

* Experiments 9, 10, and 11, although related in great detail and yielding facts of interest, are omitted.

PART II.

There are four contagious diseases in respect of which the presence in the contagious liquids, of forms of vegetation differing from those met with either after death in the normal tissues or liquids of the body, or during life in the products of primary or secondary inflammation has been established. These are smallpox, sheep-pox, splenic fever, and relapsing fever.

Discovery of the organisms in vaccine lymph.

The first statements as to the existence of organisms in the lymph of cowpox and smallpox were made by Dr. Keber* of Dantzic in 1868, who regarded them as the carriers, if not the generators, of the active virulent principle. From his description it is evident that although it is not quite in harmony with more recent observations, he had before him the objects which have since been described as micrococci by other authors, and he must therefore be regarded as the discoverer of these bodies.

In my first paper on the pathology of contagium, published in 1870,† I gave an account, accompanied by a woodcut, of certain bodies to which I assigned the name of microzymes, the presence of which I found it was usually possible to demonstrate in vaccine liquid. I was not able, however, to assert that their presence was or was not essential to the infective activity of the virus. About the same time Professor Klebs‡ described them in his Handbook of Pathology. Two years afterwards the subject was treated with much more completeness in its morphological aspects by a distinguished botanist, Professor Ferdinand Cohn§ of Breslau. His observations related both to vaccine and variolous lymph, and led to the interesting discovery that the organisms which I had described in the former are also found in the latter, and present characters so entirely similar that it is not possible to draw any distinction between them, either as regards form or development. I reproduce in full the account he gives of them as seen in fresh vaccine lymph. "Such lymph is " always found to be filled with spheroidal corpuscles, which although " they exhibit molecular motion have no motion of their own. They are " extremely small, and in their reaction on light differ little from the " serum in which they are suspended, on which account they are easily " overlooked. They can be made out with perfect distinctness under an " immersion lens of high power if the illumination is favourable, but " without these advantages it is difficult to detect them. Artificial light " is preferable for the purpose to bad daylight. After they have been " once recognised it is possible to detect them with lower powers. It is " difficult to determine the diameter of the spheroids micrometrically. I " estimate it at about three quarters of a micromillimeter ($\frac{1}{33000}''$). In " addition to these, numerous larger more refractive bodies are found in " the lymph, as regards which it is somewhat difficult to say whether they " are fat globules, or result from the further development of the others. " It seems most probable that they are cells, each of which consists of a " dark central part surrounded by a membrane indicated by a clearer ring, " an appearance often seen in stages of division. In perfectly fresh " preparations most of the corpuscles are simple, others being joined " together in pairs in a form resembling the figure 8. After the

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* Keber, Ueber die microscopischen Bestandtheile der Pocken-Lymphe. Virchow's Archiv., Vol. XLII. p. 112.

† Thirteenth Report of the Medical Officer of the Privy Council.

‡ Klebs, Handbuch der Pathologie, Vol. I. p. 40.

§ Cohn, Organismen in der Pockenlymphe. Virchow's Archiv., Vol. LV. p. 229.

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" preparation has been kept, the number of these double cells increases, " and soon chains of four begin to be distinguishable. These chains are " usually curved or in zigzag; their attachment one to another is " evidently very slight, as they can readily be displaced. After one or " two hours numerous necklaces present themselves, usually of eight " joints, which are even more readily broken up than the others. To " this displacement the groups are to be attributed; of these some " resemble sarcinæ, but it is to be observed that no true sarcinæ showing " crucial division present themselves. Obviously the very rapid and " uninterrupted multiplication of the spheroids takes place by a process " of repeated transverse division, in which the septa are parallel, so that " the resulting daughter cells are arranged in necklaces like the spores " of a penicillium. In consequence of their very slight attachment to " each other it is only at the beginning that the original grouping, due " to their mode of development, is traceable. After a few hours' obser- " vation they are seen to be all aggregated into irregular colonies or " clumps, each consisting of 16, 32, or more corpuscles. . . . . The mul- " tiplication of cells lasts for several days, the aggregations becoming " larger and larger. If the cover glass is slightly pressed, the groups " separate and the individuals forming it become isolated. . . . . In " capillary glass tubes the multiplication of colonies sometimes lasts a " long time, so that they acquire considerable size and present themselves " as flocculi. By the formation of mucus-like interstitial substance the " corpuscles become intimately united with each other, the mass being " converted into zooglœa. When this is the case the size of the indi- " vidual cells increases, their contents becoming more refractive, so as to " resemble oil drops. As these agglomerations are apt to be encrusted " with other bodies derived from the lymph, the characters which indi- " cate their origin become indistinct. It often happens that the changes " described are associated with the appearance of acicular crystals " resembling raphides."

Dr. Weigert's investigations as to the existence of micrococci in the lymphatics of the skin in smallpox.

Some months before the appearance of the paper from which the above description is quoted, Dr. C. Weigert* of Breslau published a short communication founded on the microscopical examination of the skin in persons who had died of smallpox, in which he stated that he had found the lymphatic vessels of the cutis plugged with a granular mass which exhibited all the characters of micrococci. These lymphatic vessels were met with for the most part in the tissue of the corium, underneath and around pustules in various stages of advancement. Here they in some cases occurred so constantly, that they could be found in every vertical section of the skin which comprised a pustule, though they were absent in others. In the more superficial layers of the corium, where they were most numerous, they often presented the appearance of a network. They were also found in the foci of corpuscular infiltration (minute abscesses) which in smallpox occur in the corium in the neighbourhood of pustules; here they for the most part accompanied the blood vessels around which the infiltration had taken place. It is of importance to observe that all the cases in which these appearances presented themselves, were of persons who had died early in the disease, not later than the sixth or seventh day. When, as usually happened, death had occurred at a later period, the micrococcus masses could not be distinguished—a fact which Dr. Weigert was disposed to attribute rather to the effect of the very abundant corpuscular infiltration of the tissue in concealing them, than to their disintegration or removal from the tissue.

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* Weigert, Ueber Bacterien in der Pockenhaut. Centralblatt 1871, p. 609.

It is further noteworthy that although many of the cases were markedly hæmorrhagic, the filling of the absorbents with vegetation was not confined to these cases, and indeed presented itself most distinctly where this character was conspicuously absent.

The fact that organisms of a particular form exist in the lymph of smallpox, taken in connexion with the occurrence of similar organisms in the channels of absorption leading from the pustules, suggests the probability of these having to do with the morbid process, but cannot be accepted as an adequate proof that they possess the property of reproducing or propagating the disease. For the establishment of such proof with respect to any contagium, it would have to be shown either that when deprived of its organisms, though otherwise unaltered, it is deprived of its activity, or that when the organisms are introduced alone, they manifest the contagious property of the liquid or tissue from which they were derived. An imperfect approach towards the first of these demonstrations was made in the experimental investigations set forth in my former paper; for it was shown that many contagious liquids lose their activity when they are deprived of the suspended particles in which whatever organisms they contain are included. The second must, with our present means of observation, be regarded as impossible, on the ground that the bodies in question are so minute that there is not the slightest prospect of our being able to separate them in anything like purity. But here again methods of investigation may perhaps be within reach which, although they do not come up to the strict requirements of the problem, approach it. If in any disease capable of propagation by the insertion of a contagium containing recognisable living organisms, however minute, it were in our power to observe the behaviour of these organisms during and after the act of infection, even if it were impossible to separate them from the contagious liquid or substance along with which they were introduced into the body of the infected person or animal, we should be able, by comparing the transformations or other manifestations of vital activity in the lower organism or parasite, with the functional derangements and textural changes in the higher organism resulting from the infection, to ascertain with the utmost precision the nature of the relation, if any, between the two series of phenomena.

Present position of the question as regards the contagium of smallpox.

As regards most infective or contagious diseases, such a method could not be applied, for we have no sufficient knowledge either of the door by which the contagium enters, or of its whereabouts in the organism after its entrance. In the case of smallpox these difficulties do not exist; for even if it is not possible to state precisely how the contagium is distributed from its original place of entrance, it is sufficient to know that it localizes itself in foci, each of which serves as a centre of origin of a morbid process which is as complete in itself as if there were no other. If we could, imitating Dr. Weigert's method, but carrying it out much further than he did, not merely search for our organisms at the sixth day, but at each successive period in the local process, from the first sign of functional disturbance in the *rete Malpighii* at the seat of the future papule, to the maturation of the pustule, and could trace the two developments—that of plant-life on the one hand and that of pathological and structural change on the other—going on side by side, and, as has been already explained, see that both were correlative manifestations of the same action, the object would, as regards smallpox, be accomplished. But here we are met by an insurmountable practical difficulty. No opportunity is ever likely to be afforded us of investigating the pathological anatomy of smallpox in those stages about which it is most important to obtain information.

Happily comparative pathology affords us a means of circumventing this difficulty. In the sheep there is a disease which, as regards its origin, progress, and local manifestations, is the very counterpart of human small-pox. The virus of sheep-pox, as I had the opportunity of observing in 1869, contains organisms similar to those of smallpox and vaccine. The analogy therefore is complete, so complete, indeed, that whatever can be ascertained by observation as to the behaviour of the organism of sheep-pox within the body of the infected animal, or rather of the relation between that behaviour and the pathological structural changes which take place at each focus of infection, may be applied with the greatest confidence to the elucidation of the corresponding processes in the human disease.

These considerations led to Dr. Klein's being requested to undertake the investigation of which the results are embodied in his paper on the pathology of sheep-pox.* It will probably be admitted by most readers that even if the problem has not been completely solved, the investigation has yielded results of the highest pathological value.

Besides smallpox and sheep-pox, two other diseases were mentioned as examples of the association of specific vegetable forms with contagia —relapsing fever and the splenic fever of cattle and of the horse. In the two following sections will be found a statement of what is known with reference to them.

Splenic Fever.

The first infective disease in respect of which it could be asserted with anything like probability that a specific organism was present, either in the blood or tissues, was splenic fever. The peculiar staff-shaped bodies which are apparently always contained in the liquor sanguinis in this disease were discovered in 1855, or perhaps earlier; but their significance is still matter of dispute, there being great difference of opinion, even among those who admit that they are characteristic of the disease, as to the part they play in the morbid process.

Before proceeding to discuss this question, it will probably be useful to give some account of the phenomena of the disease during life and after death.

Phenomena during life.

In the works of systematic writers on veterinary pathology there is considerable obscurity as to the definition of the term splenic fever, or (to use the German and almost as familiar word) *Milzbrand*. This arises not so much from want of clearness in the language employed, as from the effort to unite a number of clinical forms under one nosological species, without perhaps always taking sufficient pains to distinguish between what is essential and what is accidental.

The most striking feature of the disease is its extremely rapid progress. In the most rapid cases, those to which all writers refer as "apoplectic" (although the term is far from being expressive of what is observed), the disease runs its course in a few hours at most. In the ordinary cases as they occur among cattle, it lasts a day or two, its course being more or less as follows:—

An animal which perhaps for the previous day has declined food and shown signs of general disturbance, begins to shudder and to have twitches of the muscles of the back, and soon after becomes weak and listless. In the meantime the respiration becomes frequent and often difficult, and the temperature rises (Bollinger) to 3 or 4 degrees above the normal; but soon convulsions, affecting chiefly the muscles of the back and loins, usher in the fatal collapse, of which the progress

* Dr. Klein's paper will be found at p. 49.

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is marked by complete loss of power of moving the trunk or extremities, diminution of temperature, mucous and sanguinolent alvine evacuations, and similar discharges from the mouth and nares. The visible mucous membrane, congested from the first, becomes intensely so as the disease progresses.

In the horse the disease presents similar characters, but is much less acute. Partly in consequence of this, and partly as a result of the greater attention paid to the more valuable animal by veterinary practitioners, the local affection is more frequently recognised during life, so that the case is often recorded as of "acute splenic tumour." *

Pathological anatomy.

Of the phenomena revealed by dissection, those which relate to the blood itself, to the circulatory and lymphatic systems, and to the spleen (which may be regarded as a part of both), are by far the most important. In the blood the relative number of the colourless corpuscles in all excepting the most rapid cases is very considerably increased. In the horse, in consequence of the usually longer duration of the disease, this increase is so great that the blood in some cases assumes the leucæmic character. The absence of coagulability and the general tendency, not only of the liquor sanguinis, but also of the corpuscles, to soak or squeeze through from blood vessels into all the cavities of the lymphatic system, whether serous or interstitial, shows itself in the former, and particularly in the peritoneum, by the accumulation of large quantities of sanguinolent liquid, by the intense congestion of the membrane, and by the innumerable hæmorrhagic patches with which the congested parts are everywhere beset. In the subcutaneous, submucous, and subserous cellular tissue the same changes are in progress, though not in all directions in the same degree. Under the skin, infiltration of this kind often gives rise to localised swellings, which are apt to be called carbuncles. In the neck it surrounds the pharynx and larynx, and extends downwards by continuity of tissue to the anterior mediastinum, as well as among the muscles. In the abdomen it occupies the retroperitonæal space, in which all the organs are similarly soaked with liquid, turbid from the presence of corpuscular elements and discoloured by altered blood. To this condition veterinary pathologists have assigned the term typhous infiltration (*gelbe sulzige Infiltration*).

Of the enlargement of the spleen nothing can be said, excepting that it is always observed, and that taken in connection with the "infiltration" of the connective tissue already described, it constitutes the most constant pathological feature of the disease. The enlarged spleen when examined in acute cases is soft and soaked with blood, its capsule often appearing to be distended. In more protracted cases it acquires greater firmness, but does not at first diminish in size. Nothing is known, so far as I am aware, of the structural changes which take place in the splenic tissue, except in so far that even in the acute forms there is reason for believing that the augmentation of volume is not entirely the result of hyperæmia, but is also due to the multiplication of the elements of which the organ is composed.

Finally, in the digestive canal generally, and particularly in the fourth stomach and duodenum, there is usually extreme congestion of the surface and sero-sanguinolent infiltration of the mucosa. In bovine animals this condition extends along the whole course of the intestine, so that it is common to find its whole cavity filled with dark blood-

* Bollinger, Zur Pathologie des Milzbrandes. Munich, 1872. The above description is chiefly founded on the clinical observations contained in this work. The symptomatology of the disease is also fully given in Prof. Koráugi's article in the Handbuch der Allgem. und speciellen Chirurgie, Vol. I., part ii., p. 149.

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stained liquid. But in the horse the process is localised in particular places. A favourite seat of these so-called typhous or carbuncular infiltrations of the mucous membrane is the pyloric end of the stomach and the adjoining part of the duodenum; here foci of infiltration may be recognised, even before the viscus is opened, by the patches of dark lividity of the serous membrane, and by the enormous thickening of parts of the wall of the organ which correspond to them. If they are cut into when of recent origin, the intensely congested infiltrated masses are found to be beset with extravasations; eventually the central part of each focus is converted into a slough, which on separating, leaves behind it a slowly healing ulcer, often termed "typhous" ulcer. The so-called carbuncles which occur in splenic fever in the horse owe their origin to a similar process. That is, they are to be regarded not as "localizations" of the disease, but as parts of the skin of which the condition differs from the rest merely in the degree of intensity. They are often followed by sloughing of the subcutaneous tissue, with which the general infiltration manifests itself. Among cattle "carbuncles" are rarely met with, so that although one of the names by which the disease is most frequently designated is derived from them, they are by no means characteristic of it.*

Discovery of the organisms of the blood of splenic fever.

The discovery that in the blood of animals affected with splenic fever rodlike bodies are found in the liquor sanguinis, was first, I believe, made by Pollender,† who in the year 1855 described them as "fine, "apparently solid, straight, unbranched objects from $\frac{1}{400}'''$ to $\frac{1}{200}'''$ "in length and $\frac{1}{3000}'''$ in width." He noted that they possessed no proper motion, differing in this respect from ordinary bacteria. The question of their nature as well as that of their relation to the contagion of the disease was left open.

A year or two after the publication of Pollender's paper, Brauell‡ published the first of his very extensive series of researches on the contagion of splenic fever, in which he not only confirmed Pollender's discovery, but by experiments in which he communicated the disease to animals under a great variety of conditions, acquired for pathologists the greater part of the accurate knowledge they now possess on the subject. He contented himself, however, with demonstrating that the organisms found in the blood in splenic fever were characteristic of the disease, without maintaining that they were or that they were not the *causes* of its virulence, and indeed was disposed to attribute more importance to them as diagnostics than as agents in the morbid process.

Three years later the bodies in question were re-discovered by Delafond and Davaine, who in claiming a priority which did not belong to them, no doubt did so in complete ignorance of the good work that had already been done so well in Germany.

The characteristics of the rods have been recently given by Bollinger on the basis of observations made expressly for the purpose as follows:—The splenic fever bacterium measures usually from 7 to 12 micromilli-

* The best account of the pathological anatomy of splenic fever is to be found in Brückmüller's Lehrbuch der pathol. Zootomie, Vienna, 1869, p. 260 et passim. The details are founded entirely on original observations.

† Pollender, Microscopische und microchemische Untersuchungen des Milzbrandblutes. Caspar's Vierteljahrschr. f. gerichtliche und öffentliche Medicin, Vol. XIII. p. 103.

‡ Brauell, Versuche und Untersuchungen betreffend den Milzbrand, Virchow's Archiv., 1857, Vol. XI., p. 132. Weitere Mittheilungen über Milzbrand. Virchow, Vol. XIV. p. 432.

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meters ($= \frac{1}{3500}''$ to $\frac{1}{2000}''$) in length, so that it is about as long as the width of a coloured blood corpuscle. Its width scarcely admits of measurement.*

Along with the rods separate cocci are always to be found in the liquor sanguinis, which are regarded by Bollinger as certainly in organic continuity with them. The rods are entirely destitute of proper movement. In the fresh state they appear to be homogeneous, but after they have been acted on by water, or are beginning to be altered by the commencement of putrefactive change, it is seen that each rod is made up of spheroids, each spheroid consisting of a central darker part with a more transparent envelope. The most remarkable fact relating to them is that they disintegrate rapidly from the moment that the blood becomes putrescent. As they disappear, the actively moving rods and spheroids which indicate the commencement of the septic process take their place, but there is no continuity of development between the two kinds of organisms.

Conditions of communicability of splenic fever.

The following are the most important facts relating to the contagion of splenic fever which have been ascertained, either as the result of clinical or experimental inquiry.

1. The disease may be communicated by any means which involves the transference of a portion of the blood of a diseased animal to the living tissue of an animal previously healthy. It is not known that it can be propagated by any other way, for animals kept in the closest proximity to diseased ones, and placed under the most favourable conditions for infection through the air, are not infected.

2. Although the blood of animals affected with splenic fever always contains the staff-shaped bodies if it is examined at a sufficiently advanced period, the disease can be communicated by the inoculation of blood in which these bodies are either not present, or at all events not in such numbers as to admit of their being made out microscopically.

This was originally stated by Brauell, and has been recently confirmed by Bollinger as the result of experiments made expressly for the purpose of arriving at a definite conclusion on the subject. He found that the staff-shaped bodies were just as numerous in the animals infected by the injection of blood which was free from organisms as in others. In order to use this fact as a means of judging in how far the staff-shaped bodies take part in communicating to the blood its contagious property, it is necessary to bring to bear upon it what we know as to the relation of other organisms of the same class to the liquids in which they are produced. It has been proved experimentally that two liquids of the same chemical constitution, and placed under exactly the same conditions (*i.e.* both completely protected from external contamination), may stand in an entirely different relation to the ordinary bacteria which pervade all aqueous media, the difference consisting in this, that whereas one of the liquids is proved to be prone to the breeding of bacteria by their appearing in it as if spontaneously, the other may be kept for any length

* The existence of the rods as a characteristic of the circulating blood in animals affected with splenic fever is a fact now admitted by all pathologists who are conversant with the disease. It is, however, remarkable (and at first sight difficult to undestand) that many observers have expressed doubts as to their being organised living beings. Thus Leisering (Bericht über das Veterinärwesen im Königr. Sachsen, 1862, p. 29, reported in Canstatt's Jahresb. for 1863), at first took them for fragments of fibrin or for bits of tissue (*Gewebestrümmer*). F. Müller (Physiol. der Haussäugethiere, Wien, 1862, p. 163), thought that they were blood crystals. The statement made by Bruckmüller, and repeated by others (l. c. p. 261) that Virchow regarded the bacteria of splenic fever as blood-crystals, appears to be an erroneous one founded on a misquotation of an oral communication.

of time without such development taking place. The difference between the two liquids (both of which are, of course, supposed to be placed under circumstances favourable to the growth of bacteria), or rather between the properties which they severally manifest, is usually designated by the terms sterile and fruitful, of which the latter denotes that the liquid to which it is applied contains something which although inappreciable by the microscope, is already in organic development.

As regards the rods of splenic fever, it is not only possible but much more probable than the contrary, that the case is similar. Without attempting to arrive at a conclusion as to the form in which the organisms conceal themselves, it is sufficient to know that the fact of their absence in liquids of proved virulence is in itself no ground for refusing to admit either that they themselves are the contagium, or are concerned in its production, provided that other reasons exist for believing that it is so. It has been sought to demonstrate this in two ways—on the one hand, by separating the rods from the liquid and determining their pathogenic properties by experiment, and on the other, by testing the activity of the liquid after the rods have been removed from it by some process of filtration. The first of these methods, that employed or rather attempted by Davaine and the French experimenters, has led to no result; and it is difficult to see how it could yield any, first, because complete separation of such organisms from the medium in which they are contained is impossible, and secondly, because in the very act of filtration the organisms themselves would probably undergo such changes as would entirely alter their properties. If, as is probable, the activity of the rods is dependent on their vital functions, there is no reason to anticipate that they would continue to manifest that activity when "out of their element," still less that it would show itself in any descendants or progeny obtained from them by cultivation. The other method has been used by Klebs and Tiegel.* These observers have found that just as it is possible to separate the bacteria contained in ordinary septic products from the liquid in which they are suspended by filtering them under pressure through a stratum of porous porcelain, the same method can also be successfully applied to blood containing the rods of splenic fever. The result of the experiments, which it must be admitted were not so frequently repeated as could have been wished, was that the filtrate of blood (or rather the liquid of the spleen of a diseased animal), of the virulence of which experimental proof had previously been obtained, was found to be incapable of communicating the disease. Clearly there is no proof in this fact that the contagium of splenic fever is exclusively contained in the rods; but there is proof in it that the agent is, as we believe all other contagia are, a body which is incapable of solution or diffusion, and which attaches itself to concrete *particles*. An additional and to my mind a more satisfactory proof of this lies in the remarkable observation made by Brauell, that when pregnant animals are affected with splenic fever the blood of the embryo is not contagious. Brauell found in repeated trials, that in such animals, blood from the fœtal circulation could be inoculated without results. Here the placental apparatus serves not merely as a filter but as a diffusion cell, keeping back not merely solid particles, but everything which is not capable of passing through animal membranes. Splenic fever is so incapable of being communicated, otherwise than by actual translation of blood, that the fœtus is not infected by the mother.

There are facts relating to splenic fever which show on the one hand

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* Tiegel, Die Ursache des Milzbrandes. Arbeiten aus dem Berner patholog. Institut, herausgegeben von Prof. E. Klebs, 1873, p. 136.

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that the contagious property, as it exists in the circulating blood, is very transient, and on the other that there must be a form or state of the contagium in which it is remarkably persistent. The first of these is proved by Professor Brauell, who having discovered, as has already been mentioned, that the blood lost its activity from the moment that it began to show signs of putrescence, made comparative experiments for the purpose of determining at what period after death this took place, and found that after 3–5 days it had lost its activity. He also observed that as soon as the blood began to change, the motionless rods became (as he supposed) transformed into actively moving bacteria. On this point, almost the only one in respect of which his observations appear to have been inexact, he has been corrected by later observers. As has been already stated, there is no organic continuity between the two successive developments. The ubiquitous septic bacteria cannot be regarded as the progeny of their pathogenic predecessors.

Occasional latency of the contagium of splenic fever in certain localities.

That the contagium must have a state of existence in which it is in the highest degree resistant is obvious from what is known as to the distribution of the disease among cattle. On this subject observations were made and collected by Heusinger * more than 20 years ago, showing how the contagium may take up its residence in very limited localities, betraying its presence only at long intervals by the occurrence of a fresh case. A very remarkable series of observations has been published by Bollinger in his work already so often quoted. The author relates the history of what may be called a stable enzootic of splenic disease, which lasted from August 1868 to February 1872. During this period more than 10 cases occurred at intervals at one stable, situated in the middle of the village of Werikon, not far from Zürich; no cases presented themselves anywhere else in the village or neighbourhood, although the stable in question was (as usual in Swiss villages) closely surrounded by others. In whatever form, the contagious agent must have remained latent in the stable during the whole period.

The general fact of which this particular instance is the representative, has long appeared difficult to explain. How does it happen that an acute contagious disease of which the only known mode of transmission is by inoculation, and of which the duration is so ephemeral, does not perish out of existence? Clearly it inevitably would do so, had it not some other as yet unknown means of perpetuating itself. What this means is it would be too bold to conjecture. I have elsewhere given reasons for thinking that the faculty which various contagia possess of maintaining their activity outside of the body, is more easily explained as a function of life and organisation resident in the contagium itself than any other way.

One of the strongest reasons which can be adduced for thinking that in the present instance the rods are concerned in the morbid process, is to be found in the fact that like the contagious property they may be supposed to represent, they are very fugitive, and in particular, that like it and along with it they disappear at the moment that putrefaction commences. It is therefore not possible to refer to them as contrivances suited for the storage of contagium, or for its conveyance to a distance, for either of which purposes they are obviously unfit. This very consideration, however, can I think be made to appear rather as an aid to our understanding of the relation between organisation, or rather living organic form, and contagion than as a difficulty or objection. For if we turn from the specific form to what we know about the development

* Heusinger, Die Milzbrandkrankheiten der Thiere und des Menschen. Erlangen 1850, p. 345.

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and life history of common bacteria, and indeed of the beings belonging to the same group in general, we find the same thing. Just as in the case of the specific contagium, we are compelled to recognise two states of existence, one enduring and latent, the other active but fugitive; so among these plants we find one condition in which the growth and multiplication of individuals and the individual life is extremely short, another in which the vital activities of the organism are stored up for the future, the individual being for this very end endowed with the power of resisting external disintegrating agencies, and thereby of enduring for an indefinite period.

The common ubiquitous bacteria, those which are concerned in putrefactive changes, are known to be in their ordinary active state easily destroyed. Thus they are unable to survive complete desiccation, or a temperature higher than 80° C. On the other hand, it is equally well ascertained that masses containing bacteria are not deprived of the power of originating new generations of these organisms by heat, unless they are either subjected to a temperature considerably higher than that of ebullition, or boiled for a very long period. The reason of the apparent discrepancy is to be found in the fact that the bacteria have two modes of existence, the one characterized by permanence and resistance, the other by rapid development and short duration; that in all bacterial masses which have the power of resisting high temperature, *e.g.*, in cheese, there exist, in addition to the ordinary forms of readily killed bacteria, other living particles of more stable structure.

The properties of such bodies, to which Professor Cohn assigns the name of lasting spores (*Dauersporen*), are only just now beginning to occupy the attention of mycologists. I have referred to them here in order to show how completely the biography of a schizomyces represents all the phases of the process of contagion.

Acute diseases of man apparently identical with splenic fever—*Mycosis intestinalis.*

During the last few years the pathology of splenic fever has acquired an even wider interest than it had before, from the publication of a series of cases of a rapidly fatal disease affecting the human subject, which presents the characters of splenic fever, and turns out on investigation to be identical with it. The first of these cases was published by Professor Buhl * at Munich in 1868. It is that of a man aged 32, who died after a very short illness, of which the chief feature was rapid collapse with vomiting. After death the stomach and duodenum exhibited a number of circumscribed foci of infiltration with intense congestion, and extravasations of blood in the infiltrated tissue. The spleen and the lymphatic glands in relation with the affected parts were enlarged, and the peritonæum was full of liquid. The ætiology of the disease, *i.e.*, the origin of the infection, was not recognised, but it was found that the foci of infiltration were infested by masses of organisms, which according to Bollinger, who was present at the examination, exhibited the character of the rods of splenic fever. The same structures were found in great abundance in the blood of the portal system. In other parts of the circulation the rods were absent, but spheroidal corpuscles occurred which were described as *conidia.*

The affection was termed by Buhl "*mycosis intestinalis.*" Shortly afterwards two other cases were recorded by Professor Waldeyer, now of Strasburg.† In one of them, that of a slaughterer, whose occupation pointed to the source of infection, the nature of the disease was suspected during life. After death the suspicion was confirmed by the complete

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* Buhl, Mycosis intestinalis. Centralblatt, 1868, p. 8; and Zeitschr. f. Biologie, 1870, p. 129. Bollinger, loc. cit. p. 114.

† Waldeyer, Ueber Mycosis intestinalis. Virchow's Archiv. Vol. LII. p. 541.

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correspondence of the lesions with those of splenic fever in the horse. As in Buhl's case the microscopical investigation showed that masses of zooglœa existed in the affected tissues, and that rod-like microzymes were to be found in the circulating blood, particularly in that of the portal vein. Other cases soon followed, all rapidly fatal, and all exhibiting pathological appearances of the same kind, the most constant being the enlargement of the spleen, and the circumscribed hæmorrhagic infiltrations of the intestines, resulting in more or less extensive sloughing of the mucous membrane, and associated with serous exudations, infiltration of the subserous tissue, and hyperæmic enlargement of the lymphatic glands in relation with the infiltrated parts.

Whatever doubt remained as to the identity of *mycosis intestinalis* with splenic fever was removed by the appearance of a communication by Dr. Münch of Moscow,* who was able to state from the results of his own dissections in the "Workman's Hospital" at that place, that in all the cases in which he had occasion to examine the bodies of men who had died of disease contracted by infection from animals, the intestinal lesions and the condition of the other internal viscera corresponded closely with those described by Buhl and Waldeyer. In commenting on this paper, Bollinger points out that in Heusinger's great work on splenic fever, a whole series of cases of communication of the disease to man are recorded, in which the appearances after death corresponded with those which have been described, and that in these, as in those recently recorded by Münch, the primary pustule (*pustula maligna*) at the seat of inoculation, often supposed to be the one pathognomonic lesion of splenic fever in man, was by no means a constant feature. Out of 28 cases recorded by Münch (1867–71) seventeen exhibited a primary pustule, which in all but two was carbunculous. But in the other 11 cases, there was nothing whatever to be found on the skin.

As regards the morphological relations of the organisms found in mycosis intestinalis with those of splenic fever, further investigation is required. So far as the former have been described they agree completely with the others, as may be readily seen by comparing the drawings of Wagner,† taken from a case of mycosis, with Cohn's or Bollinger's representations of the "rods" of splenic fever.

The identity of the two forms being admitted, Buhl's and Waldeyer's anatomical investigations afford a key which was before entirely wanting, to the understanding of the so-called "localizations" of splenic fever. This key consists in the demonstration that the "*sulzige Infiltration*," of which we read so constantly and repeatedly in the descriptions of the veterinary pathologists, is a process of which it is *the* characteristic that the tissues of the infiltrated part become infested by myriads of microzymes of a particular kind, so that the presence of these bodies is as much a part of the process as the emigration of the colourless corpuscles from the blood vessels is a part of ordinary suppuration.

Further than this it is not possible to go, until the initial stages of the process, the early structural changes, have been investigated in the lower animals. For this investigation the field is open, and it is in the highest degree desirable, in the interests of humanity, that it should be undertaken. The material is abundant; what is required is that the highest pathological knowledge and anatomical skill should be employed

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* Münch, Mycosis intestinalis und Milzbrand. Centralblatt, 1871, p. 803. Heusinger, loc. cit., p. 597.

† Wagner, Ein Fall von tödtlichen Pilzkrankheit—Mycosis intestinalis. Leipzig, 1872.

in its investigation. If this is done results of the greatest value may be confidently anticipated. We may hope thereby to acquire a knowledge of one more of those malignant processes by which acute disease destroys human as well as animal life, processes of which we may be perfectly certain that their danger is in proportion to our ignorance of their nature.

Relapsing Fever.

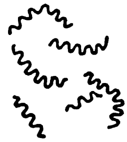
In the epidemic of relapsing fever which prevailed in Berlin from November 1867 to May 1868, Dr. Obermeier, whose attention had been called to the question of the relation between specific organic forms and contagia by the publications of Professor Hallier, investigated the blood microscopically in 82 cases. In general the results were negative. In some cases, however, he noted appearances of which he did not at the time understand the full significance, but was prevented from investigating the subject further by the cessation of the epidemic.

Discovery of the spirilla of relapsing fever.

When relapsing fever again appeared in Berlin in 1872, the inquiry was resumed. In the very first case which was investigated, the bodies, to be referred to in the following paragraphs as *spirilla*, were discovered in the blood. His first communication on the subject to the Berlin Medical Society* was based on 12 cases, in all of which the organisms were observed. On the 26th of March Dr. Obermeier published a second series of observations; † 20 new cases had been investigated, in nine of which the blood had been examined daily. The results of these examinations showed that the presence of the organisms in the blood was associated with the morbid process so closely, that as soon as the pyrexia disappeared they disappeared with it, reappearing when the patient again fevered in the relapse.

Soon after the death of Dr. Obermeier in August 1873,‡ a third series of observations were communicated by Dr. Engel to the Berlin Medical Weekly Journal.§ They were founded on the examination of the blood in 18 cases in the Charité Hospital at Berlin, under the care of Professor Frerichs. They confirmed in every particular the statements of Obermeier, deriving additional value from the exact observations they contained as to the time which intervenes between the onset of pyrexia and the first appearance of the organisms.

During the same year the epidemic prevalence of relapsing fever in Breslau afforded additional opportunities for investigating the subject. The first results of these inquiries were communicated by Dr. Weigert to the medical section of the Silesian Scientific Society on September 12, 1873.‖ The morphological and botanical characters of the organisms were subsequently determined by Professor Cohn, who was kind enough to send me the sketch of which the woodcut is a copy. The clinical relations of the subject have been since worked out by Dr. M. Litten in a report on the epidemic, founded on observations in the Allerheiligen Hospital in Breslau. Of this report I subjoin an abstract.¶



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* Report of the meeting of Feb. 26, 1873. Berlin. klin. Wochenschrift, 1873, p. 152.

† l. c., p. 391.

‡ Dr. Obermeier died of cholera while engaged in his scientific investigations.

§ Engel, Ueber die Obermeierschen Recurrens spirillen, l. c., p. 409.

‖ Berlin. klin. Wochenschrift, 1873, p. 589.

¶ Die Recurrens-Epidemie in Breslau im Jahre 1872–73, von Dr. M. Litten Assistenzarzt am Hospital zu Allerheiligen.

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Clinical observations.

The total number of cases observed by Dr. Litten was 448. Of 400 which were carefully recorded, 43½ per cent. had two paroxysms, 35½ had three paroxysms; in six out of the 400 cases (1½ per cent.) there was only one attack, in seven cases there were four, and in three five attacks. This leaves 17 per cent. of the cases unaccounted for, in which the course of the disease was insufficiently determined.

The mean duration of each paroxysm and intervening period of pyrexia is expressed in the following numbers. The mean duration of the first attack was 6·6 days, of the second 4·9 days, of the third 3·1 days, of the fourth 3·1 days, and of the fifth 2·3 days. The mean duration of the period between the first and second attack was 8 days, that between the second and third 9 days, between the third and fourth 6·3 days, between the fourth and fifth 8·3 days.

Nosological character.

During the paroxysms, the pyrexia for the most part exhibited an intermittent type, in which the morning and evening temperatures differed from each other so much, that the case resembled one of quotidian ague. In many of the cases the temperature rose a degree or two before the critical fall, the rise being accompanied by a shivering of considerable duration, followed by profuse sweating. In the majority, however, the temperature began to sink before the sweating came on. In addition to the ordinarily observed critical phenomena (sweating, epistaxis, vomiting, diarrhœa, deposit of sediment in the urine, &c.), the crisis was accompanied in seven cases by a herpetic eruption about the lips and nose.

The course of the disease as regarded variations of temperature corresponded exactly with those usually observed in relapsing fever. There were, however, some cases in which irregular paroxysms presented themselves. This happened particularly among those patients in which the intensity and duration of the fever gave ground for alarm, although there were no complications. In addition to these there were other cases in which the disease beginning as relapsing fever assumed eventually a distinctly tertian or quotidian form (p. 288), the patients having been previously exposed to malaria; and here it was most interesting to observe that the spirilla, which had been constantly found during the true relapses, were not present during the ague paroxysms. The author records temperature curves of several cases illustrative of these facts.

Of the pathological signs of the disease during life, the enlargement of the spleen was the most constant. It was present in 96 per cent. of the cases, and could be detected much earlier in the disease than is possible in typhus or intermittent. The diminution of the splenic tumour did not take place until some days after each crisis, but the increase began from the very commencement of each relapse. The swelling was always attended with pain in the left hypochondrium; the pain was increased in inspiration. In some cases the enlargement of the spleen was accompanied by a corresponding enlargement of the liver, the duration of which was similar.

The most frequent complication in the epidemic was bronchial catarrh. It occurred mostly at an early period in the disease, often as soon as the second or third day, whereas in typhoid it usually does not happen till the beginning of the second week. In some cases it was attended with œdema of the lungs, which in two weakly old persons terminated fatally. True croupous pneumonia occurred in 28 cases, of which 17 were one-sided, 11 double. The access of the complication was marked in the younger patients by rigors. In all of these cases the sputa were characteristic, and the physical signs were those of genuine lobar pneumonia. Of the 28 cases, of which 23 were fatal, the attack hap-

pened in 11 during the second interval of apyrexia, and in 8 during the first.

Most of the patients suffered during the paroxysms from headache and giddiness; some were somnolent and unable to answer questions; others talkative, but answered rationally when spoken to. In some cases with very high temperatures (42° C.) there were no marked symptoms of cerebral disturbance.

Pains in the joints were a frequent complication, and often lasted for some weeks after the decline of the disease. Usually, however, they were experienced only during the paroxysms. Still more constantly the patients suffered from severe pains in the muscles, affecting either groups of muscles or the whole muscular system. The author dwells on the painful and distressing character of this symptom as experienced by himself. It usually declined during the apyrexia, recurring with greater intensity in the relapse. The muscles usually affected were those of the neck and lower extremities. The spirilla could not be detected in the muscular tissue.

Of the 448 cases observed, 32 died (7·2 per cent.), five in the first apyrexia, eight in the second paroxysm, 15 in the second apyrexia, and the remaining four in subsequent stages. With reference to the direct causes of death, 23 were attributed to pneumonia, as above stated; five persons died without complications at the height of the fever, no direct cause of death being made out at the autopsy.

Origin and progress of the epidemic.

Dr. Litten begins his history of the epidemic with a very complete account of the earliest cases, and of their relation with each other. The first person attacked was a female tramp, who came to Breslau from another district (Neisse), in which no previous case was known to have occurred, lodged for the night in a Refuge, and took ill on the following day. The second case was that of a woman who had slept in the next bed to the other. Both patients in succession were admitted into the Allerheiligen Hospital, soon after which a woman convalescent from erysipelas, who occupied the next bed to one of the patients, and a nurse were attacked. A married sister of the nurse and three of her children subsequently became ill. In the meantime a separate focus had established itself out of the town, in a hamlet called Wilhelmsruh. Here 14 persons, belonging to four families, *all of which inhabited the same room*, were attacked; all the other inhabitants of the hamlet, although some of them occupied rooms in the same building, remained free. They were transferred to a previously unoccupied building which had just been opened as a Refuge in the town. Into this three other persons not affected with the disease were also received, of whom one only escaped infection. Several persons who left the Refuge became the centres of "tenement-epidemics" (*Stuben Epidemien*), in which as a rule nearly all the inmates of the invaded houses were attacked; but the disease did not spread in localities from which the affected persons were removed.

During the progress of the epidemic 21 persons, chiefly attendants, were attacked in the hospital, most of whom had not come into contact with the patients until the latter had been subjected to the warm bath, and had changed their ordinary clothing for that of the hospital.

When a number of persons were attacked in one room there was always an interval of several days between the first and the second case, similar intervals also occurring as a rule between the succeeding attacks, so that each "tenement-epidemic" lasted several weeks.* Wherever

* In illustration of this the author gives a very striking table shewing the order in which the several members of the four families at Wilhelmsruh were attacked.

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a room was inhabited by several families it was observed that the persons belonging to one family (in other words, those who wallowed on one heap of straw) were attacked sooner than those belonging to others, even though they were in the same room, so that the attacks occurred more or less in groups corresponding to families.

The author finds it impossible to regard poverty and want of food as the principal or only causes of the disease, and attributes its spread entirely to personal contagion. He states that at the commencement of the outbreak no special conditions of the kind referred to existed. The harvest had been good, and if provisions were dear, wages were relatively high. Persons were attacked under circumstances altogether removed from those of starvation, and among the very destitute it was observed that many who had previously for months spent night after night in the open air, and had remained exempt from the disease, were very soon attacked when, in consequence of the opening of the new Refuge in the town, they were brought into close relation with others.

In the distribution of the cases in those parts of the town in which they were most numerous, the only condition which seemed to have a distinct influence was overcrowding. The facts related show that during the winter in question this condition prevailed in Breslau to a frightful extent.

Observations relating to the spirilla.

Dr. Litten gives the following summary of his observations:—The spirilla of Obermeier are found only in the blood of persons affected with the disease, and present themselves invariably during the paroxysms. They are never observed during the interval of apyrexia. In more than 100 cases the spirilla were found without exception. In other patients affected with acute or other infective diseases, *e.g.*, pneumonia, erysipelas, acute rheumatism, scarlatina, measles, typhoid, variola, and particularly ague, the blood was examined with negative result. Notwithstanding, however, that the spirilla occur so constantly during the paroxysms, they cannot usually be made out immediately after the commencement of the rise of temperature. Often 24 hours and sometimes two or three days may elapse before they can be detected. Obviously the fact that in most instances they cannot be seen until some time after the first symptoms have manifested themselves, affords no proof that they did not previously exist. They invariably disappear before the critical defervescence, but not at any definite time; sometimes they may be found immediately before the temperature falls, at others they cease to be visible a day before. If, as occasionally happens, there is a transient fall of temperature in the middle of an attack (pseudo crisis), the spirilla do not disappear.

The number of spirilla found varies considerably. Whereas in some cases it is necessary to examine several preparations before a single example is met with, in others the field of the microscope swarms with them. It appears probable that the number diminishes as the paroxysm approaches its termination. The most striking fact in relation to them which presents itself to the observer is their uniformity in size and aspect. They form spiral fibrils of which the convolutions are extremely small. That this spiral appearance is not a mere result of their motion is clearly shown by the observation that after all motion has ceased it is as distinct as before. Their motions are of three kinds. In the first place, they exhibit undulations which progress along the course of each fibril, and secondly, flexions, occurring sometimes at one point sometimes at another of their axes; thirdly, they are locomotive. Both the locomotive and undulatory movements are very active, and are often communicated to the corpuscular elements of the blood, so that it

sometimes happens that the presence of the bodies may be detected by the motions of the coloured disks, and particularly by a peculiar appearance of glistening undulation which courses over them, and is produced by the passage of spirilla above or below them. The other movement (of oscillation) is observed principally when the spirilla are becoming languid, as, for example, towards the end of a paroxysm. At the height of the pyrexia, on the other hand, the axis of each spiral is straighter, although the convolutions are quite as distinct. They often assume very peculiar forms, sometimes being in circles, so as to look like coloured blood disks, at others in figure of eight; at other times they attach themselves to each other in long chains which stretch over the whole field. In this last condition they do not exhibit active movement, but two spirilla so united are often seen to break away suddenly from each other, as if they were undergoing division.

It is very easy to distinguish the spirilla from the fibrils of coagulating fibrin, from which they differ both in their greater delicacy and in their mobility. Their spiral form alone is sufficient to make it easy to recognise them.

They can be best kept alive out of the body in serum. In a preparation surrounded with oil the motions continue for 24 hours. In half per cent. solution of common salt they can also be observed for several hours, but eventually their motions decline and they become altered in appearance; the wavy spiral movement continues after all locomotion has ceased. On the addition of distilled water they die instantly. Solution of caustic potash not only arrests their movements but dissolves them.

The influence of temperature on the movement was investigated with the following results:—On raising the temperature of the stage of the microscope gradually to 60° C. no effect was produced. As soon as this point was passed the movements became languid. By the time that 65° was reached they had entirely ceased. No effect was observed on cooling the preparation to the temperature of freezing. When it was kept for some time on ice the movements eventually ceased.

Observations were also made for the purpose of determining whether during the disappearance of the spirilla from the blood, *i.e.*, at the critical period of defervescence, they could be found in any other organ; the results were negative.

The presence of the large colourless transparent cells, described by Obermeier, Ponfick, and others as characteristic of relapsing fever, was observed in a good many cases. These cells are of very various form, the spheroidal being the most common. Their size varies from twice to four times, or more than four times, that of a colourless blood corpuscle. They are mostly beset with coarse strongly refracting granules. They were observed both during the paroxysms and the intermissions. In many of the cases the relative number of colourless corpuscles was obviously increased.

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Addendum.

In the section of the foregoing paper relating to diphtheria, I stated that there were several pathologists who, on the ground of experiment, have come to the conclusion that the pathological process which is set up in the animal body by inoculating portions of diphtheritic concretion is not merely a mycosis, but the specific disease itself; in other words, that the distinction between diphtheria as defined nosologically and the diphtheritic mycosis is not founded on any pathological difference.

Attempts to show that in the artificial production of diphtheritic processes in animals, there is actual transmission of the disease.

Of these observers, Dr. Letzerich,* of Braunfels (Nassau), and Dr. Oertel,† of Munich, are the most important. The former is the author of several papers on diphtheria, of which I give the titles in a note. These papers contain various observations relating to diphtheria as it presents itself clinically, which serve to illustrate the intimate association of the development of microzymes in the affected parts with the morbid process; the author also records numerous experiments showing that when the disease is communicated by inoculation, its characteristics reappear in the infected animal, even those which belong to its more remote complications. Dr. Letzerich's facts lose much of their value from their not being set down with that simplicity which ought to characterize all scientific writings. His papers, moreover, contain a great deal of questionable mycology, in which the patient reader is apt to lose himself in his search after objective facts.

The mémoire of Dr. Oertel, published three years ago, also embodies anatomical and experimental investigations relating to the effect of inoculating animals with material derived from the larynx in cases of diphtheritic laryngitis in children. Like Letzerich, the author found that a disease having well-defined pathological characteristics, and in particular associated with nephritis, could be produced by such inoculation; and further, that it could be communicated from one animal to another without losing any of its distinctive features. He further showed that the disease in question, whatever were the local peculiarities given to it by the tissue in which it was ingrafted, was always a mycosis; in other words, that all the "localizations" of the disease were associated with the presence in the affected part of innumerable microzymes. As regards the agents of infection, he concluded that their presence was the only constant characteristic of the contagion, for he found that the disease could be produced by the transference to the tissues of a healthy animal of even the smallest fragment of any diseased tissue, and that all diseased tissues contained microzymes in greater or less numbers. The following short account of a series of experiments in which the disease was transmitted through five successions of animals, will enable the reader to form an estimate of the bearing and significance of the research.

The material for the first inoculation was removed about 12 hours after death from the trachea of a child, aged five, affected with laryngeal diphtheria. It consisted of the usual cellular elements embedded in a fibrinous stratum, which was infiltrated with innumerable micrococci. Of this, three fragments as large as pinheads were introduced into the

* Letzerich, Beiträge zur Kenntniss der Diphtheritis. Virchow's Archiv, Vols. XLV., p. 327; XLVI., p. 229; XLVII., p. 516. Monographic der Diphtherie, Berlin, 1872. Die Entwickelung des Diphtheriepilzes, Virchow's Archiv, Vol. LVIII., p. 303 (1873).

† Oertel, Experimentelle Untersuchungen über Diphtherie; Deutsches Archiv für Klin. Med., Vol. VIII., pp. 242–354.

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trachea of a rabbit, which died about 36 hours afterwards with the characteristic signs of croup, and exhibited in the air passages and in other organs the pathological appearances to be immediately described. With the tracheal concretions of this animal a second rabbit was inoculated, and from that a third. The latter in its turn afforded material for the inoculation of two pigeons, of which each served as a source of contagion for two rabbits. Of these two pairs of rabbits, one pair were inoculated subcutaneously, the other two being infected by the injection of the virulent material in minute quantity into the larynx. In all, the results were similar, the pathological changes and symptoms being quite as characteristic in the last of the series as in the first. The following description is that of a rabbit which received the disease in the air passages after four previous transmissions, the immediate source of infection being a pigeon.

The animal had died 96 hours after inoculation, the symptoms of laryngeal affection having lasted longer than usual. The tracheotomy wound had completely united, but underneath it there was a cavity lined with greyish material of pulpy consistence; the subcutaneous tissue of the whole body, excepting that of the back and neck, was infiltrated with sero-sanguinolent serum; and the subcutaneous lymphatic glands were enlarged and hyperæmic. From the vocal cords downwards to the middle of the trachea, a tubular, whitish, tolerably adherent membrane, of about $\frac{3}{8}''$ in length and $\frac{1}{12}''$ in thickness, covered the mucous membrane. This membrane was continuous by a narrow neck with a second membranous concretion, which extended over a great part of the larynx and the lower half of the epiglottis. In the kidneys, the epithelium of the convoluted tubes was swollen and granular, and in many instances detached. Masses of micrococci occupied the spaces between the glomeruli and their capsules, and were also distinguishable in the tubes. Capillary hæmorrhages presented themselves in great numbers in the intertubular tissue, and many of the tubes were choked with blood corpuscles. The muscular tissue—especially in the neighbourhood of the trachea—exhibited, in addition to germination of the interfascicular tissue, peculiar changes, which the author has examined into with great care. He finds that in all infected animals the contents of the muscle tubes look as if they had shrunk from the sarcolemma, and in doing so had split transversely into cylindrical fragments, between which the empty tubular sheath can often be distinguished. In the blood, micrococci and bacteria existed in enormous numbers. They were also present in the enlarged lymphatic glands, and indeed in all the affected tissues.

The reader will observe that in the series of inoculations of which a summary has been given, several links in the chain of transmissions of the diphtheritic affection from animal to animal consist of subcutaneous inoculations. In the animals so infected, the changes in the blood and tissues which may be regarded as the signs of infection, were not distinguishable from those observed when diphtheritic material was injected into the air passages, the only difference being that there was no laryngitis. In commenting on these experiments the author says:—"The "pathological process which results from the introduction of diphtheritic "material under the skin or into the tissue must be regarded as a truly "specific one, excited by a contagium identical with that which is "present in the concretions on the surface of mucous membranes. *No "such process can be induced in the animal organism by any putrescent "or decomposing material.* The general infection produced in the "animal body by diphtheritic inoculation extends centrifugally from the "seat of inoculation through the tissues, and shows no preference for

"any one organ in particular; the participation of the kidneys, for "example, being merely a result of the existence of the infecting "material in the circulating blood."

Here all turns on the statement which I have printed in italics. To prove this, Oertel's experiments are insufficient. For the present the question whether or not the induced diphtheritic affection of rabbits is excited by a contagium identical with that of "Diphtheria," must remain open.

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Report on the Pathology of Sheep-pox, by Dr. Klein.

App. No 2.

On the Contagium of Variola Ovina, by Dr. Klein.

Variola ovina, or sheep-pox, is a disease which, although it is not communicable to man, and possesses a specific contagium of its own, very closely resembles human smallpox, both as regards the development of the morbid process and the anatomical lesions which accompany it. This correspondence is so complete, that it cannot be doubted that the pathogeny of the two diseases is the same. That is to say, that whatever explanation can be given of the way in which the material cause or contagium produces its effects in the one case will also serve as a key to the understanding of the other. The present investigation was therefore undertaken in the confidence that the application of the experimental method to the investigation of the ovine disease, would not only yield results of value, as contributory to our knowledge of the infective process in general, but would throw special light on the pathology of smallpox.

In the following pages I propose, after giving an account of the method of investigation employed, to describe, first, the microscopical characters of the sheep-pox virus, and to compare them with those of vaccine lymph. I shall then proceed to detail the results of my investigation of the pathological changes which occur in the affected parts of the skin.

Section I.—*Method of Investigation.*

The purpose of the inquiry being to determine the nature of the pathological process, of which the cutaneous eruption is the most prominent, and probably the most important manifestation, it was necessary to examine the affected skin anatomically in all stages of the development of the disease. In order to obtain the material for this investigation, I communicated the disease by inoculation to a sufficient number of sheep. In this way I obtained specimens of skin, corresponding to each successive period in the development of the pustule, which had been removed from the animal in a perfectly fresh state. With the aid of the complete and continuous series of preparations of which I thus became possessed, I was enabled to study the process in a most satisfactory manner.

The lymph used for inoculation was obtained from two sources, one quantity having been sent to me by Professor Chauveau, of Lyons, the second by Professor Cohn, of Breslau. In some of the inoculations the lymph was first diluted with from fifteen to twenty times its volume of half per cent. solution of common salt; in others it was used undiluted. No difference was observed as regards the results between the diluted and undiluted liquids; in all cases the instrument employed for insertion was a Pravaz syringe.

Mode of inoculation.

A drop having been drawn into the steel canula of the instrument (the width of which does not exceed a fortieth of an inch), it was passed under the surface of the skin, as in subcutaneous injection. In order to avoid bleeding, great care was taken to direct the needle in such a way that it penetrated the true skin as little as possible. Before discharging it, the canula was always slightly drawn back, so as to leave the channel previously made by its point free for the reception of the expelled liquid. It will be understood that in using a subcutaneous syringe for inoculation in the manner above described, the only part of the instrument which is occupied by the liquid to be inserted is the

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extremity of the steel tube; the extremely small quantity of liquid which is thus employed is ejected at the desired moment by the compression of the air behind it.

Although there can be no doubt that the nature of the pathological process in the skin is the same whether it is determined by the direct insertion of the virus into the affected part, or is conveyed to it by the circulation, yet it appeared clear that the value of the results would be impaired if the investigation extended only to the local effects produced by inoculation. I therefore felt it to be very desirable (considering it was out of the question to obtain opportunities of studying the disease as it occurs naturally) to induce it in a form resembling the natural one as closely as possible.

Natural sheep-pox, as acquired by the ordinary modes of infection, is characterised by a general eruption, the first appearance of which is accompanied by an accession of fever.

I had not only learned from my own observation that no general eruption could be induced by inoculation, but found on referring to authorities, that in those countries in which inoculation is carried on on a very large scale with a view to the protection of animals from attacks of the disease, it is extremely rare to meet with instances in which secondary pustules present themselves in addition to the primary one at the seat of insertion; it was therefore necessary to employ some other method.

I fortunately succeeded completely in producing a general eruption by introducing the sheep-pox virus into the circulating blood. Having diluted the liquid with from fifteen to twenty times its bulk of the solution of chloride of sodium already referred to, I injected it directly into the external mammary vein of a healthy sheep. At the same time that this was done I inoculated the animal in the usual way, making in all ten insertions. My object in employing both methods simultaneously was, that I might utilise the animal to the utmost. I was desirous on the one hand to induce a general infection, and thereby a general eruption; and on the other to obtain an additional supply of primary pustules for the completion of the investigations I had already made. I also thought it of great importance to compare the anatomical characters of the primary and secondary eruption in the same animal.

The injection and inoculation were performed on the 1st of April; the primary papules made their first appearance on the 4th. On the 7th several small secondary papules appeared on the lips and around the mouth, and increased rapidly in number during the succeeding three days. At the same time the eruption extended to other parts of the body, but the papules were most numerous in the axilla and on the belly. It is to be noted that the interval of time between the appearance of the first and last papules of the secondary eruption was considerable, so much so that the pustules on the lips had already formed crusts at the time that the eruption was first visible in other parts. In this case, as in the others, the primary pustules were from half an inch to an inch and a half in diameter; most of the secondary ones did not exceed a quarter of an inch, but there were a few of those which appeared latest on the chest and belly which measured half an inch or more.

Section II.—*Microscopical characters of Sheep-pox Virus.**

Clear lymph, which had been kept for several days in a sealed capillary tube, was diluted with thoroughly boiled half per cent. saline solution.

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* The description relates to a specimen of lymph sent by Prof. Cohn.

One portion of the diluted liquid having been reserved for further experimental inoculations, the remainder, which was intended for microscopical examination, was found to contain the structures represented in Fig. I. *

Fig. I.

1. Transparent masses of various sizes, containing granules, some of which are small, pale, and indistinct, others large and shining.
2. Transparent spheroid bodies arranged in small groups composed of couples or necklace-like chains; each is bordered by a sharp line as if consisting of transparent contents enclosed by a membrane.
3. Highly refractive micrococci grouped so as to form dumb-bells or sarcina or small colonies.
4. Groups of decolorised blood-corpuscles, with micrococci occupying the interstices between them.
5. Bacteria, of which the smaller ones correspond to *Bact. Termo* of Cohn.
6. Colonies of *Bacterium Termo.*
7. Micrococci mostly in couples or in small groups. Each spheroid is surrounded by a greenish envelope, or in some cases by what appears to be a thin membrane; the couples, in consequence of their being united by a transparent connecting substance, resemble rods with terminal swellings; these bodies are about twice the size of the micrococci referred to above.
8. Groups consisting of spheroids of two kinds, the larger corresponding with (2), the smaller with (3); on careful examination it is found that between the two kinds of bodies there are transitional forms, of which the characters are intermediate both as regards size and appearance. These groups appear to correspond to those figured by Cohn as microsphæra vaccinæ.

In the same preparation after it had been kept at the temperature of incubation for 24 hours, the transparent masses referred to above (1), were found to have undergone the remarkable changes shown in Fig. II.

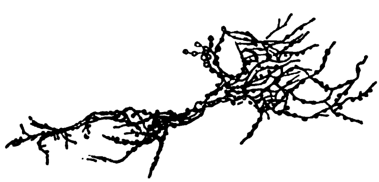

Fig. II.

* The reference numbers on the figure correspond to those of the paragraphs.

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Under a high power it is seen that they consist of spherical granules of different sizes arranged in rows, each granule being united to its successor hy pale transparent substance, so that the whole appears to be made up of a feltwork of delicate granular filaments, among which separate granules are seen here and there. In preparations kept for 48 hours the larger masses are seen to have broken up into smaller ones, in which the individual fibrils can be more easily traced, while the granules themselves have assumed characters which correspond to those of the micrococci (3), and pale spheroids (2) seen in the fresh lymph. This conversion of the granules contained in the masses into spheroids and micrococci, goes on for some days, so that these bodies multiply very considerably in the liquid.

Examination of perfectly recent Lymph.

A drop of lymph obtained on March 24th from a pustule of an animal that had been inoculated March 10th, was examined microscopically without dilution, and was found to contain, in addition to granular pus corpuscles and coloured blood corpuscles, numerous small highly refractive granules, either isolated or in couples, which exhibited molecular movement. After having been kept at 32° C. for 27 hours, it exhibited the following structures, (Fig. III.) in addition to those already mentioned :—

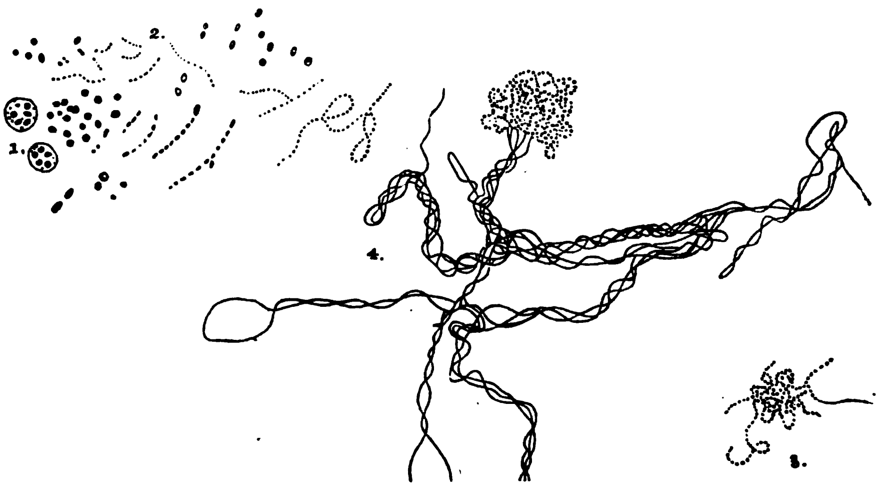

Fig. III.

* 1. Pus corpuscles, of which the substance has become swollen and transparent, each containing from two to six homogeneous slightly refractive spheroids. These bodies, of which the diameter is less than half that of a coloured blood corpuscle, are also seen in considerable numbers in the free state ; they possess a slightly greenish colour, and are perfectly homogeneous, differing in both of these respects from nuclei of pus corpuscles. When not enclosed in pus corpuscles they occur either isolated or in couples ; in form they are usually spheroidal, but are occasionally oblong, showing a more or less marked constriction in the middle. Along with these, other forms exist, in which it can be made out that the body, if a spheroid, consists of a highly refractive smaller

* The numbering of the paragraphs corresponds as before, to that of the Fig. (III.)

granule (micrococcus) contained in a transparent envelope ; or if oval or rod-like, of two such granules held together in a similar manner. Between these and the free micrococci to be immediately described, it is easy to observe the transition.

2. By the repeated division of the spheroids above described, the dumb, bells and necklaces shown in the figure * are formed ; the constituent micrococci of the necklaces are held together by a connecting transparent substance. Sometimes they are all of the same size, but more frequently one is larger than the rest, and presents the appearance of a greenish transparent pear-shaped body, which may or may not contain a highly refractive granule. The necklaces, which have grown to a great length and have become much convoluted, are apt to break up into shorter chains, forming
3. Groups from which the free ends of the filaments project. By the coalescence of these groups of convoluted chains, colonies, consisting of micrococci closely packed together, are produced, which correspond in appearance to the Zooglæa of Cohn ; these colonies are often connected together by
4. Long filaments, some of which still show a necklace-like structure, while others are apparently smooth and homogeneous. Twenty-four hours later the colonies were found to have increased in number and size; some of the individual micrococci had also undergone changes, having not only acquired larger dimensions, but having assumed the appearance represented in Fig. I. (7.)

From the appearance above described I conclude that the highly refractive spheroid is the only form that can be regarded as characteristic of the lymph of sheep-pox in its active condition.

Section III.—*Anatomical Investigation of the Changes which occur at the Seat of Inoculation.*

1. The development of the primary pock may be divided into three stages, of which the first is characterised by progressive thickening of the integument over a rapidly increasing but well-defined area ; the second, by the formation in the rete Malpighii of vesicular cavities containing clear liquid (the "cells" of older authors), in which sooner or later organic vegetable forms are developed ; the third, by the impletion of these cavities with pus-corpuscles. It is to be noted that the division into stages is less marked than in human small-pox.

2. The process commences in the rete Malpighii and in the subjacent papillary layer of the corium—in the former, by the enlargement and increased distinctness of outline of the cells, and by corresponding germinative changes in their nuclei ; in the latter, by the increase of size of the papillæ, and by germination of the endothelial elements of the capillary blood-vessels.

3. It is next seen that the interfascicular channels (lymphatic canaliculi) of the corium are dilated and more distinct ; that the lining cells of these channels are enlarged and more easily recognised than in the natural state ; and that in the more vascular parts of the corium, the channels are more or less filled with migratory or lymph corpuscles. At the same time, the lymphatic vessels, of which the canaliculi are tributaries, can be readily traced, in consequence of their being distended with a material which resembles coagulated plasma.

* The particles forming the necklaces present the appearance of solid bodies ; this is not well shown in the engraving.

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4. About the third day after the appearance of the pock, the contents of the dilated lymphatics begin to exhibit characters which are not met with in ordinary exudative processes. These consist in the appearance in the granular material already mentioned, of organised bodies, which neither belong to the tissue nor are referable to any anatomical type—viz. of spheroidal, or ovoid bodies having the characters of micrococci and of branched filaments. In Fig. IV. a lymphatic vessel of the corium

Fig. IV.

is seen in section filled more or less completely with micrococci. In some parts the spheroids are aggregated in the zooglæa form, so that the mass appears granular, in others it presents a filamentous aspect, the spheroids being in necklaces or chaplets. In the upper part of the figure a blood-vessel (*c*) is shown in section which is sheathed in the lymphatic channel, at (*d*) a valve is shown with masses of micrococci on

either side of it; (*bb*) indicate interfascicular channels containing connective-tissue corpuscles. In Fig. V. a similar lymphatic vessel of the

Fig. V.

corium is represented, of which the contents have the characters of a mycelium, and consist of branched filaments. In Fig. VI. the same

Fig. VI.

structure is seen, but the interlacing of the filaments is so dense that the whole presents the aspect of a felt-like mass.

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5. The process thus commenced makes rapid progress. After one or two days the greater number of the lymphatics of the affected part of the corium become filled with the vegetation above described; and on careful examination of the masses, it is seen that they present the characters of a mycelium, from which necklace-like terminal filaments spring, each of which breaks off at its free end, into conidia. In most of the filaments, a jointed structure can be made out, and in the larger ones, the contents can be distinguished from the enclosing membrane by their yellowish-green colour.

The necklace-like filaments are well seen in Fig. VII. They are

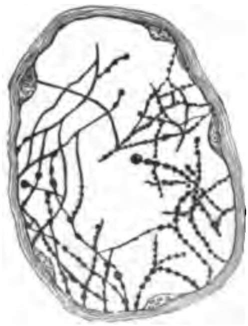

Fig. VII.

contained in a lymphatic vessel of the corium similar to those represented in Figs. IV., V., and VI.

Separated conidia, in a state of germination, are shown in Fig. VIII., as seen under a much higher power.

Fig. VIII.

6. At the same time that these appearances present themselves in the corium, those changes are beginning in the now much thickened rete Malpighii, which are preparatory to the formation of the vesicular cavities already mentioned. By a process which I propose to designate horny transformation, having its seat in the epithelial cells of the middle layer of the rete Malpighii, a horny expansion or stratum appears, lying in a plane parallel to the surface, by which the rete Malpighii is divided into two parts, of which one is more superficial, the other deeper than the horny layer. Simultaneously with the formation of the horny layer the cells of the rete nearest the surface of

the corium undergo very active germination, in consequence of which the interpapillary processes not only enlarge, but intrude in an irregular manner into the subjacent corium. At the same time, the cells immediately below the horny stratum begin to take part in the formation of the vesicular cavities, some of them enlarging into vesicles, while others become flattened and scaly, so as to form the septa by which the vesicular cavities are separated from each other.

The whole of this process is well shown in Fig. IX.,* which repre-

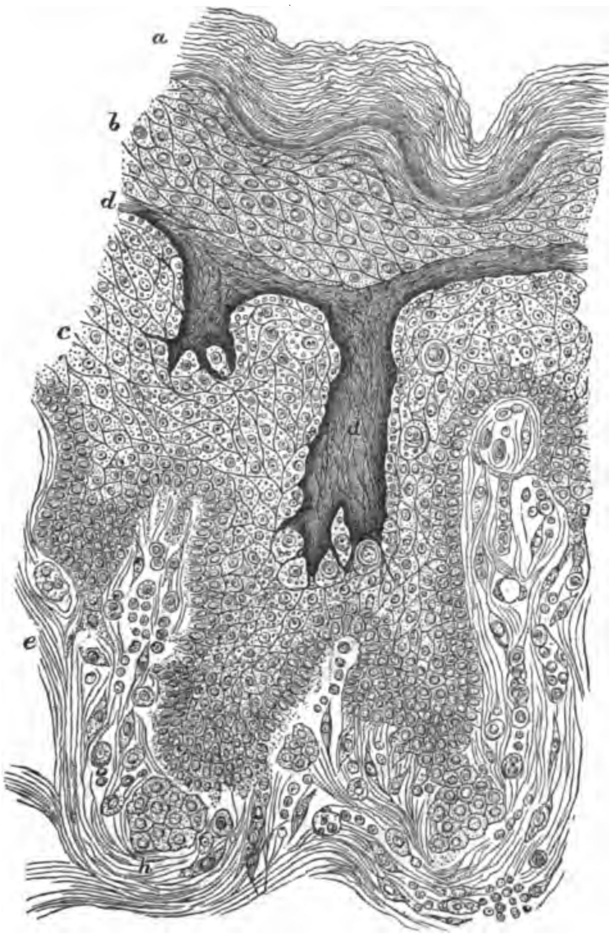

Fig. IX.

sents a vertical section through the central portion of a primary pock on the eighth day.

The stratum corneum is unaltered. The newly-formed horny layer by which the rete Malpighii is abnormally split into a superficial and a deep layer, is seen to be formed by the transformation of the cells which lie next to it on its superficial aspect. On its deep surface are cells

* (*a*) Stratum corneum, (*b*) superficial layer of *rete Malpighii*, (*c*) deep layer of do., (*d*) newly-formed horny layer, (*e*) superficial or papillary layer of corium.

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which are much enlarged and contain vacuoles; they present the appearance to which pathological histologists frequently apply the term dropsical. It is by the subsequent dilatation of these enlarged cells that the vesicular cavities ("cell" of the older authors) are formed; between them the septa are seen composed of flattened and scaly cells which, as above described, extend from the horny layer towards the interpapillary processes. The drawing further shows the remarkable changes which take place in the papillary processes themselves simultaneously with the formation of the horny layer. In consequence of the very active germination of the cells of which these processes consist, they send down conical or cylindrical sprouts into the corium; it sometimes happens that the end of one of these sprouts is cut off, so that it presents itself in the section as an island of cells (*h*) surrounded by the tissue of the corium.

7. The vesicles, once formed, increase in size and number. Originally separate, and containing only clear liquid, they coalesce, as they get larger, into irregular sinuses, and are then seen to contain masses of vegetation similar to those which have been already described in the lymphatic system of the corium—with this difference, that the filaments of which the masses are composed are of such extreme tenuity, and the conidia are so small and numerous, that the whole possesses the characters of zooglœa rather than of mycelium. There appears to me to be little doubt that these aggregations are produced in the same way as the others, viz., by the detachment of conidia from the ends of filaments. The characters of the vegetation contained in the vesicular cavities are well shown in Fig. X. The contents of a single vesicle, as

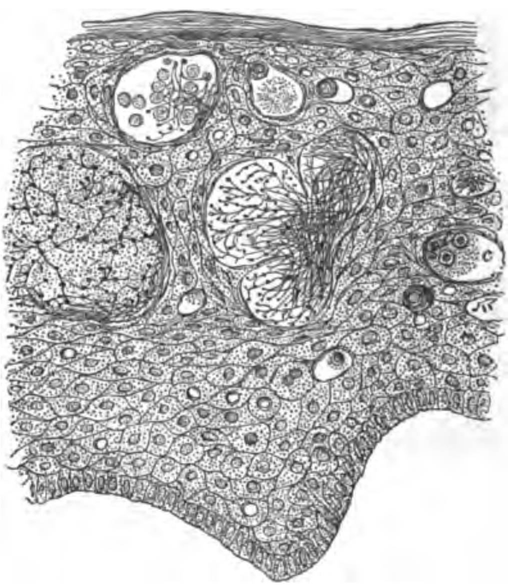


Fig. X.

seen under a much higher power, are represented in Fig. XI. In the earlier stages of the process the cavities contain scarcely any young cells. Sooner or later, however, so much of the rete Malpighii as lies between the horny stratum and the papillæ becomes infiltrated with migratory lymph-corpuscles. The process can be plainly traced

in the sections. At the period of vesiculation, *i.e.*, at a time corresponding to the commencement of the development of the vesicles in the

Fig. XI.

rete Malpighii, the cutis (particularly towards the periphery of the pock) is infiltrated with these bodies. No sooner has the coalescence of the vesicles made such progress as to give rise to the formation of a system of intercommunicating sinuses, than it is seen that the whole of the deep layers of the rete Malpighii become inundated (so to speak) with migratory cells, which soon find their way towards the cavities, and convert them into microscopical collections of pus-corpuscles, the formation of which is proved to be due to migration from the corium, not only by the actual observation of numerous amœboid cells *in transitu*, but by the fact that the corium itself, before so crowded with these bodies, becomes, as the pustulation advances, entirely free from them.

Section IV.—*Anatomical Investigation of the General Eruption.*

The anatomical characters of the secondary pocks are substantially the same as those of the primary, the most prominent features being thickening of the rete Malpighii and œdema of the corium, combined with the presence of lymph corpuscles around the blood-vessels, with similar corpuscular infiltration of the lymphatic canalicular system in the neighbourhood.

In general the stage of pustulation is reached more rapidly in the secondary pustules than in those which are the direct result of inoculation. Thus, in the eruption on the lips the contents of the vesicular cavities became purulent not later than the third or fourth day; after the appearance of papules on the chest the development was more tardy. The infiltration of the cutis and papillary tissue was greater towards the periphery than towards the centre, especially in those pustules that had lasted longest and exhibited most distinctly a central depression. There were also considerable differences as regards the changes which, in the primary pustule, result in the splitting of the rete Malpighii into two layers. The peculiar transformation which in the primary pustule goes on to such an extent as to result in the formation of a horny layer, which is of such thickness and so well marked that it can be distinguished in the section by the naked eye, is represented

in the secondary pustules by a change of the same kind, which, however, is very partial in its extent and distribution, and affects only a few cells of the middle layer of the rete. Connected with this there is a considerable difference in the mode of the formation and the arrangement of the vesicular cavities. They appear in great number simultaneously in the middle layers of the rete Malpighii, and are generally found much nearer the corium than in the primary pocks. It is further to be noticed as a collateral fact that in consequence of the number and progressive dilatation of the vesicles at the expense of the deepest layers of the rete, the inter-papillary processes become obliterated, so that the corium is marked off from the rete by a line which is almost as even as it is in sections of the natural skin. As a further result of the distinction of the vesicles, it is sometimes seen that the deepest cells of the rete are altered in form by compression. As regards the distribution of the vesicles in the secondary pustule, it is to be noticed that even in those pocks that exhibited a marked central depression, the most numerous and well-developed vesicles were found towards the centre; this is clearly inconsistent with the supposition that the depression is caused by the disappearance of previously existing vesicles.

As has been already stated, the vegetations contained in the lymphatics of the corium, as well as those occupying the vesicular cavities, presented the same characters as those which have been already described in the previous section. In some vesicles the mycelium is embedded in a finely granular matrix which is to be regarded as coagulated plasma; in others the matrix is almost homogeneous, and is stained slightly by carmine and hæmatoxyline. The mycelium itself, as well as the spores which devolve from it, exhibit a bright and shining appearance. Eventually the mycelium is transformed by a process of rapid fructification into a mass of micrococcus resembling zooglæa, the characters of which are not to be distinguished from those of the similar masses which are met with in the primary pustules when examined at a later stage of their development.

No. 3.

Report of Anatomical Researches into the Lymphatic System and its relation to Tuberculosis, by Dr. Klein.

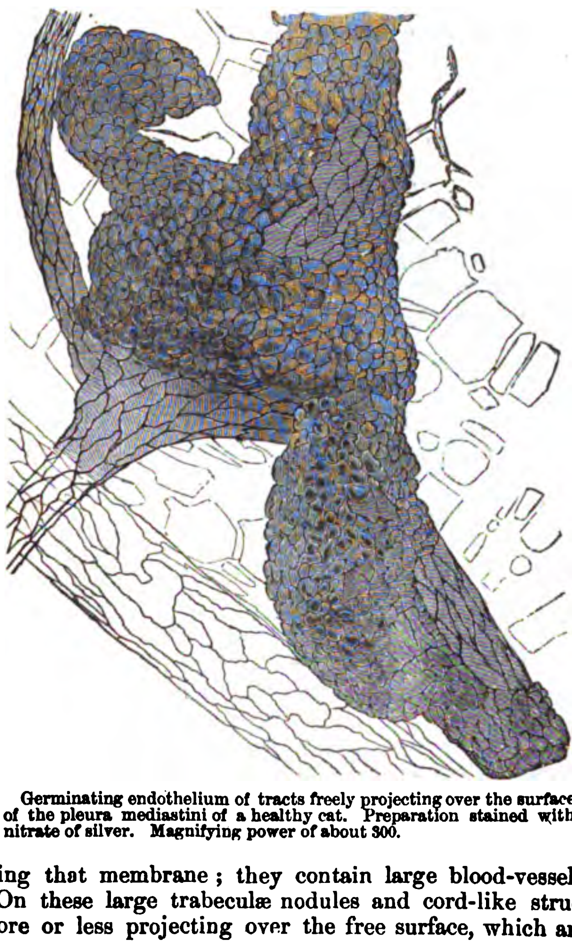
Part I.—Lymphatic System of the Serous Membranes.

A. *Normal Anatomy.*

1. *The Endothelium of the free surface of the Serous Membranes* in the normal condition is composed not only of a layer of flattened cell-plates, but in some places, hereafter to be described, of cells, which appear polyhedral, club-shaped, or like short columns; their substance is a distinctly granular protoplasm, even in the fresh condition, and their nucleus is either marked by a constriction, or completely divided into two. Endothelial cells of this kind may be called *germinating endothelium*, for they are in constant prolescence, giving origin to lymphoid cells, which gradually become detached from the free surface.

Such germinating endothelial cells are found in smaller or larger groups on the fenestrated omentum, on the large and small trabeculæ,

Fig. 1.



Germinating endothelium of tracts freely projecting over the surface of the pleura mediastini of a healthy cat. Preparation stained with nitrate of silver. Magnifying power of about 300.

constituting that membrane; they contain large blood-vessels and fat tissue. On these large trabeculæ nodules and cord-like structures are found more or less projecting over the free surface, which are covered

generally on one side only with germinating endothelium. This kind of endothelium is seen not only in the fenestrated omentum of the dog, cat, guineapig, rat, and monkey, but also on the omentum of the rabbit, which is very little, or not at all, fenestrated; here the germinating endothelium is also found on the surface of certain patches of structures of different sizes, which are isolated or in groups, or form a continuous cord. The pleura mediastini of dog and cat are especially rich in nodules and cords, covered with germinating endothelium.

The mesogastrium of frogs (especially of female frogs in the winter months) exhibits also groups of germinating endothelium, the cells of which are often provided with delicate cilia on the free surface.

So also the mesentery and the septum cisternæ lymphaticæ magnæ are in some places covered with small groups of germinating endothelium; the germinating cells in the latter membrane being also in female frogs provided with cilia, especially during the spawning season.

On the peritoneal surface of the diaphragm there are stripes of small germinating endothelial cells covering certain lymphatic vessels, which will be afterwards described as radiating straight lymphatic capillaries.

2. *The Cellular Elements of the Matrix of the Serous Membranes* generally consist of (*a*) flattened, more or less branched, isolated cells; and (*b*) migratory cells. In some places, however, the flattened cells

Fig. 2.

Silver preparation of the pencilled pleural surface of centrum tendineum of a guineapig suffering from slight chronic inflammation.

a, Lymphatic capillaries. *b*, Lymph-canalicular system lined by connective-tissue corpuscles.—Magn. × 300.

are so close to one another, and so little branched that they resemble a group of endothelial cells. The first lie in a preformed system of spaces (the lymph-canalicular system of Recklinghausen), in such a manner that the nucleated part of the flattened cell occupies a lacuna, while their branches lie in a corresponding system of canals,—the anastomosing canals

between neighbouring lacunæ. Through this lymph-canalicular system the amœboid cells pass, *i.e.* migrate. The first kind of connective-tissue corpuscles are to be regarded as an imperfect, *i.e.* disconnected endothelial lining of the lymph-canalicular system. This fact is brought out in a striking manner when the lymph-canalicular system happens to be dilated either naturally or after injection.

In certain parts of the serous membrane, especially in the vicinity of the larger blood-vessels, the connective-tissue corpuscles undergo remarkable changes, being converted into true lymphatic glandular structures. These structures are generally at first small, and not much elevated above the surface of the membrane; but as they grow they become more elevated, presenting the appearance of larger or smaller nodules or cords. They are very numerous in the omentum of the rabbit and of other mammalian animals (cat, dog, rat, guineapig, and monkey), but most numerous in the pleura mediastini of the cat and dog.

They may be described as follows:—

(*a*) Patches and nodules, the matrix of which consists of groups of ordinary flattened branched cells, which on the one hand multiply by division, so that the organ increases in size, and from which on the other hand lymphoid cells originate. The branched and lymphoid cells lie in the lymph-canalicular system. At an early stage of development they do not contain blood-vessels; at a later period they possess a special system of capillary blood-vessels. By growing in length they join one another, and form cords and tracts.

FIG. 3.

From a fresh oedematous omentum of a guineapig suffering from chronic peritonitis.

a, Lymphatic vessel. *c*, Its endothelial wall. *b*, Peri-lymphangeal nodule. *d*, Its capillary blood-vessels. *e*, Lymphoid cells.—Magn. × 300.

(*b*) In many of these structures the branched cells of the matrix are gradually converted into a delicate reticulum, in the meshes of which the lymphoid cells are contained; at this stage they are generally provided with blood-vessels, and entirely resemble lymph follicular structures.

(*c*) There are, however, other nodular and cord-like structures which do not take their origin from the ordinary connective-tissue corpuscles of the matrix of the serous membrane, but which develop within lymphatic vessels in connection with their lining endothelium. These nodules and cords possess the same structure as those mentioned in (*b*); *i.e.* they resemble true lymph follicular structures.

The first two kinds of nodules and cords are to be designated as peri-, the third as nedo-lymphangeal structures; for, as will afterwards be seen, all three kinds are developed in connection with the wall of lymphatic vessels; but the two first grow from the outside, and the third from the inside.

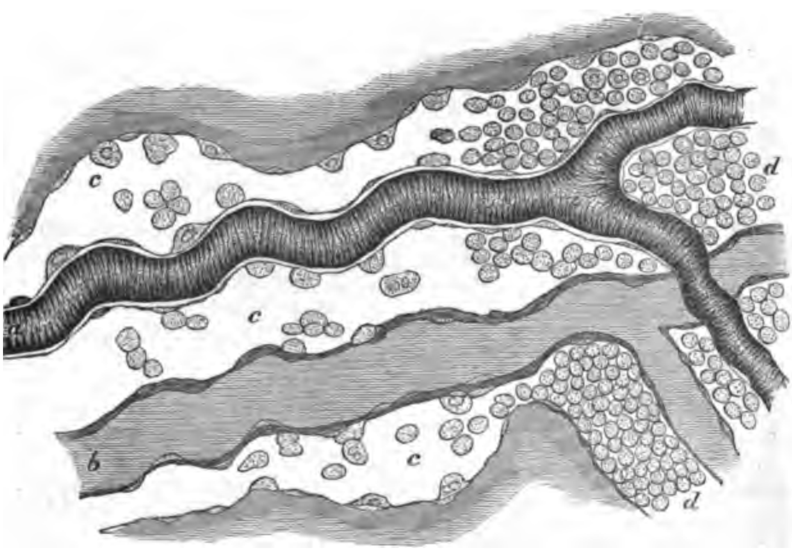
App. No. 3.

On the Lymphatic System and its relation to Tubercle, by Dr. Klein.

Fat tissue stands in close relation to the perilymphangeal nodules; for fat cells are developed not only from connective-tissue corpuscles, but the fat tissue of the serous membranes develops, as a rule, from the perilymphangeal nodules, the matrix of which is converted into fat cells. It is therefore evident that in a given serous membrane the number of lymphangeal structures stands in inverse relation to that of fat tracts. The proportion in which perilymphangeal nodules are converted into fat tissue differs considerably in different serous membranes. Thus, *e.g.* this change takes place considerably in the omentum and mesentery of the cat and dog; whereas it occurs very little in the pleura mediastini of these animals. In general it may be stated that the tendency to this change is greatest in the mesentery and least in the pleura mediastini.

3. *The Lymphatic Vessels of the Omentum.*—A. In the rabbit these are differently arranged in different parts. In the neighbourhood of the great curvature of the stomach and in the portion of omentum covering its pyloric end, where there is a rich network of lymphatics, they are related to the large blood-vessels in such a way that a group of the latter has two lymphatics, one on each side, communicating with one another by transverse and oblique lateral branches. The lymphatics are also distributed independently of large blood-vessels, chiefly between and around the lymphatic patches mentioned above. Concerning their structure, there is little to add to what is already known. They are wide vessels, the walls of which consist of one layer of endothelial plates; these

Fig 4.



From an oedematous omentum of a monkey suffering from chronic peritonitis.
a, Artery. *b*, Vein.
Both these vessels invaginated in a lymphatic *c*, which contains numerous lymph-corpuscles.—Magn. × 300.

latter, in the large lymphatics which accompany the blood-vessels, being of a short, spindle-like, and somewhat sinuous outline. They possess valves and corresponding sacculated dilatations, and are to be considered as the main lymphatic trunks.

The other lymphatics, distributed in the tissue, are not different in calibre or in the form of the endothelium; but they are either without valves, or have them only here and there, while they are provided with

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sinus-like dilatations springing from their sides. These are to be considered as the lymphatic capillaries. In the portion of omentum covering the anterior wall of the stomach, the conditions are somewhat different. Here the lymphatics are only seen in company with the blood-vessels, which in this part are rarely large, the vessels of common occurrence being the smaller arteries and veins, the courses of which are often isolated for considerable distances. The arrangement of the lymphatics may be summed up as follows:—A single lymphatic vessel is accompanied on one side frequently by a vein, sometimes also by an artery ; the lymphatic possesses at certain points saccular dilatations, and receives occasionally a lateral branch. These vessels have mostly a sinuous endothelium. Or, secondly, a blood-vessel is accompanied on each side by a lymphatic ; these are disposed exactly as in the former case, and communicate by cross branches. Finally, it occurs not unfrequently that the blood-vessel runs within a lymphatic, *i.e.* the blood-vessel is invaginated.

B. The lymphatic vessels of the omentum and pleura mediastini of other mammalian animals (as in the cat, dog, rat, guineapig, and monkey) have an arrangement similar to that in the same organs of the rabbit, *i.e.* they accompany the larger blood vessels, either singly or more frequently in pairs, and are in a few cases of an invaginating character. As regards their structure, they appear to consist simply of a wall composed of a single layer of endothelial cells.

Two points concerning the origin of lymphatic vessels from the tissue are of great importance. (*a*) The lymphatic vessels are in continuity with the connective-tissue corpuscles in such a way that on the one hand the *lumen* of the vessel is in direct communication with the lymph-canalicular system, and on the other hand the *endothelium* of the vessel is in unbroken continuity with the branched connective-tissue corpuscles occupying that system. Where the connective-tissue corpuscles form the nodules and cords above described as perilymphangeal structures, the surrounding lymphatic vessel is seen to be in such a relation to them that the lumen of the lymphatic vessel loses itself in the labyrinth of lymph spaces in which the branched cells of the matrix of the peri-lymphangeal structures are situated; and that these latter cells are in continuity with the endothelial wall of the lymphatic. So that properly speaking these peri-lymphangeal structures appear to be situated only in the wall of the lymphatic vessel. (*b*) The invaginating lymphatic vessels have an important relation to the origin of those lymph-follicular nodules and cords that we designated above endolymphangeal structures. A lymphatic vessel invaginating a vein is seen to become dilated into a wide sac where the vein receives its capillary tributaries, which are themselves invaginated in that sac ; or a lymphatic vessel that accompanies a vein possesses a blind saccular dilatation, in which the system of capillary vessels belonging to that vein is contained like the glomerulus of a Malpighian corpuscle of the kidney. In either case it may happen that the lumen of the invaginating lymphatic vessel gradually loses itself in a labyrinth of spaces by the growth of a reticulum of branched cells within its cavity, and in connection with its endothelial wall ; the meshes of the reticulum are occupied by lymphoid cells originating from that reticulum. In this way we are enabled to understand the formation of true lymph-follicular nodules and cords, to which from their being within a lymphatic vessel the word endolymphangeal may be applied.

4. *The Lymphatic Vessels of the Mesentery.*—The mesentery possesses two kinds of lymphatic vessels first, vessels which run from

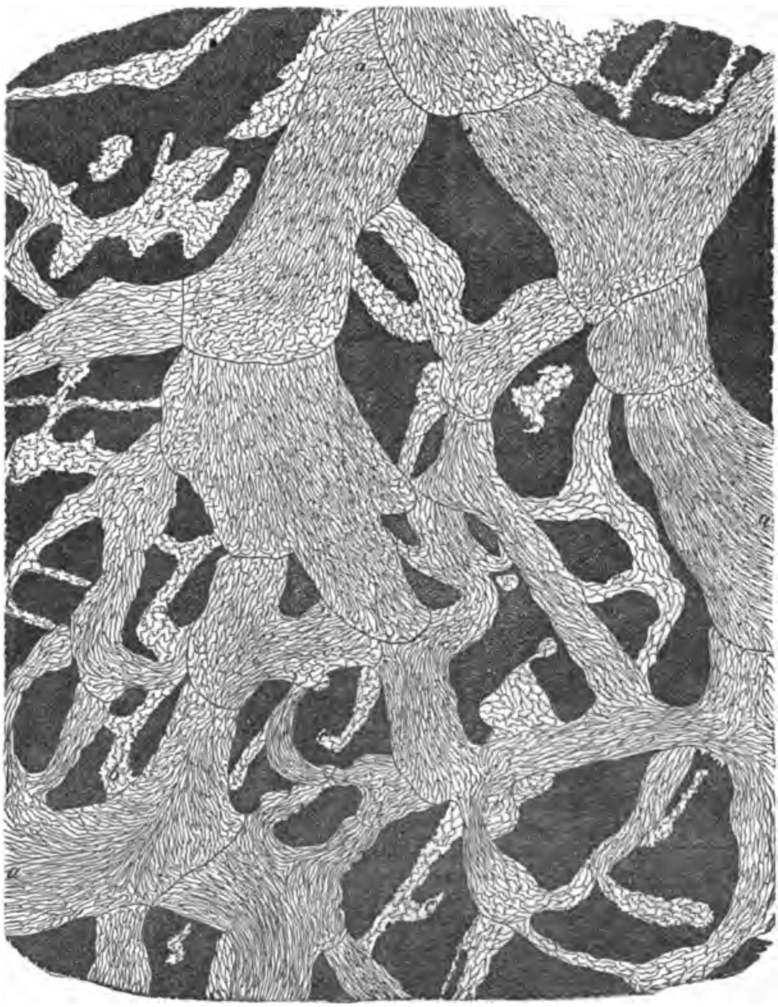
the intestine to the roots of the mesentery in order to enter the mesenteric glands; and, secondly, vessels which belong to the mesentery itself. The vessels of the first kind are situated in the chief trabeculæ of the mesentery, along with the large blood-vessels, which run to and from the intestine. These lymphatic vessels are distinguished by the number of their valves and by their continuous well-developed circular muscular coat. Their endothelium is spindle-shaped, like that in the lymphatic trunks in general. The vessels of the second kind are: (*a*) large lymphatic vessels, which like the others accompany the larger blood-vessels. They may be single, but are more frequently in pairs; in the former case the lymphatic is situated between the arterial and the venous trunk; in the latter the artery and the vein lie both between the two lymphatics. They anastomose with each other by a few wide branches. Here and there they possess a valve; they have no muscular coat, their wall consisting only of one layer of endothelium, which is more or less elongated and spindle-shaped. In many places the breadth of the endothelial cells is not much inferior to their length. Lymphatic vessels of this kind are often found to invaginate an arterial or venous trunk for a longer or shorter distance, especially with their large saccular dilatations. These dilatation-sinuses are constantly found in the lymphatics of mammals, as well as in those of frogs. Especially in rana temporaria, and in bufo, I have come across not a few mesenteries in which, instead of lymphatic vessels accompanying blood-vessels, there was a system of lymph-sinuses, situated behind each other and communicating with each other by small openings. This is determined principally by the arrangement of the ground-substance, for in the cases just referred to there were large trabeculæ in which the blood-vessels and nerve-trunks were imbedded, and from which small branches sprang at regular intervals, anastomosing with each other so as to form a mesh work. Seen from the surface it looked exactly like a fenestrated membrane. The meshes were occupied by the lymph-sinuses above mentioned. In frogs not only a single blood-vessel or nerve-trunk, but sometimes the whole trabeculæ containing the blood-vessels and the nerve-trunk may be invaginated in a lymphatic vessel.

(*b*) Besides those lymphatics which are found in and close around the chief trabeculæ of the mesentery, there are others which belong to that portion of the membrane which is intermediate to these trabeculæ. These are more or less wide vessels, having no valves; their wall is a single layer of rhombic endothelium with sinuous outlines. They correspond to the structures generally called lymphatic capillaries, and generally accompany the smaller veins. In the pencilled silver-stained mesentery of the dog, cat, monkey, and frog, they are very easy to demonstrate. They anastomose with each other, forming a wide net-work, and like the vessels previously mentioned, are provided with dilatation-sinuses. In those mesenteries where there is little fat tissue, and where consequently it can be easily seen that the lymphangeal *plaques* and tracts consist of branched cells, it is also evident that these patches and tracts are always accompanied by one or more lymphatic vessels.

5. *The Lymphatic System of the Centrum Tendineum of the Diaphragm.*—From Recklinghausen's experiments it is well known that the very abundant lymphatics of the centrum tendineum are distinguishable into lymphatic trunks and lymphatic capillaries, the former being provided with valves and lined by spindle-shaped endothelium, the latter having no valves, having a lumen of variable size, numerous excavations, and sinuous endothelium. Recklinghausen states that some of the lymphatic capillaries of the pleural serosa have a blind end

like a horn curved inwards, at which point they lose themselves in the lymph canalicular system. Ludwig and Schweigger-Seidel have further shown that the lymphatics of the pleural serosa of the centrum tendineum of the rabbit communicate with lymphatic vessels, which run between the tendon-bundles. As these bundles have on the abdominal surface a radiating and on the pleural a circular arrangement, the two lymphatics which run between them have respectively a radiating and a circular course, and the former are called by Ludwig and Schweigger-Seidel superficial, the latter, deep lymphatic channels. My researches

Fig. 5.



Silver-stained preparation of a pencilled normal centrum tendineum of rabbit.
a, Large lymphatics with valves. *b*, Lymphatic capillaries. *c*, Lymphatic capillaries dipping down between the tendon-bundles.—Magn. × 50.

teach me the following facts respecting the distribution of the lymphatics in the centrum tendineum of the rabbit. They are for each half arranged in two systems, an anterior and posterior. The vessels of the anterior system are distributed upon the outer and anterior (that is

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larger) portion of the anterior quadrant, and upon the outer (that is smaller) portion of the posterior quadrant. Those of the posterior system are distributed upon the inner posterior (that is smaller) portion of the anterior and upon the inner (that is larger) portion of the posterior quadrant. (The relative number of lymphatics is greater in the posterior quadrant than in the anterior). The efferent trunks of the anterior system course along the *pars costalis* of the diaphragm, and usually unite on the posterior surface of the xiphoid cartilage on each side, with one or two large vessels, which run along with the mammary vessels towards the sternal gland. On their way they join with those lymphatics that come from the intercostal spaces.

The efferent trunk of the posterior system is single on each side; it mounts obliquely towards the middle line, and opens into the thoracic duct near the point where the latter emerges from the diaphragm. Each system communicates with the corresponding one of the other side by a few large vessels. The vessels of each system have the following characters: the large vessels possess valves and a wall consisting of spindle-shaped endothelium; they are situated chiefly between the pleural serosa and the tendons, or in the depth of that serosa. The capillaries that run into these vessels have no valves, are provided with

Fig. 6.

Natural injection of the lymphatics of the centrum tendineum of rabbit.
a, Large lymphatics of the pleural side. *b*, Straight lymphatics of the abdominal side.—Magn. × 80.

irregular excavations, and their wall consists of sinuous endothelium. There are two kinds of capillaries: *a*, those that lie chiefly in the pleural serosa, and are of a variable breadth; *b*, those that lie between the

tendinous tissue. These run, consequently, in a straight course in two directions, so that we may distinguish deeper capillaries running in a circular direction and more superficial capillaries running in a radial direction. These two kinds of straight lymphatic capillaries generally communicate where they cross each other, by an extremely short branch at the points where their walls come in contact; or a superficial straight capillary may sometimes be seen to bend at a right angle, so as to continue its course as a deep straight capillary. The deep straight capillaries represent the vessels of communication between the superficial straight capillaries and the lymphatic vessels that lie in the pleural serosa. As a rule, the deep straight capillaries, before they join a lymphatic trunk, run a short distance, in a more or less wavy course, between the tendon and the pleural serosa.

The question which now presents itself is, What is the physiological value of the straight lymphatic vessels? Ludwig and Schweigger-Seidel attribute to them an important *rôle* in absorption. According to these authors they are widely dilated when the diaphragm is in the position of inspiration and its muscles and tendons are in action, whereas they are compressed during expiration, the lymphatics of the pleural surface of the diaphragm being in the opposite condition. Consequently, the diaphragm acts like a pump on its lymphatics. (The free communication of the lymphatics with the peritoneal cavity, by means of stomata, will be discussed hereafter.) This, however, is not the only way the straight lymphatics act. We have mentioned already that the lymphatics of the diaphragm are arranged in an anterior and a posterior system, the former discharging itself by trunks that run towards glands behind the sternum, the latter by a wide short trunk that runs directly into the thoracic duct. Now the straight lymphatic capillaries are the vessels by means of which these two systems communicate, and this is their chief function. As the deep straight lymphatic capillaries and the superficial ones represent, as we have seen, only one category of vessels, we are justified in saying that this category of lymphatic capillaries discharges itself in two directions: one freely into the thoracic duct, and a second less freely towards the sternal gland. We shall see afterwards that the straight lymphatic capillaries, both deep and superficial, are in free communication with the peritoneal cavity, by means of vertical lymphatic canals (stomata of authors); consequently we have to correct the diagram of Ludwig and Schweigger-Seidel representing the lymphatics as a single pump, to a diagram of a pump with two cylinders, one corresponding to the pleural vessels of the anterior system, the other to those of the posterior system, while the pipe connecting the two cylinders corresponds to the straight capillaries, and the piston tube to the vertical lymphatic canals. It must be borne in mind, however, that the two cylinders act simultaneously.

The superficial straight lymphatic capillaries are not the only capillaries that are to be met with on the abdominal surface of the centrum tendineum of the diaphragm of rabbits and guineapigs. Near the median line of the anterior quadrants, and near the large blood-vessels that pass through the diaphragm, there exist lymphatic capillaries of a winding course, provided with numerous dilatation-sinuses. They are in communication with the straight lymphatic capillaries. In some places two neighbouring superficial straight capillaries anastomose with each other by means of a transverse branch provided with sinuses, which belong to the peritoneal serosa.

6. ***Relation of the Lymphatic Vessels to the surface of the Serous Membranes.***—The lymphatic system of the serous membranes communicates with the free surface, *i.e.* with the serous cavity, in two ways, (a) by

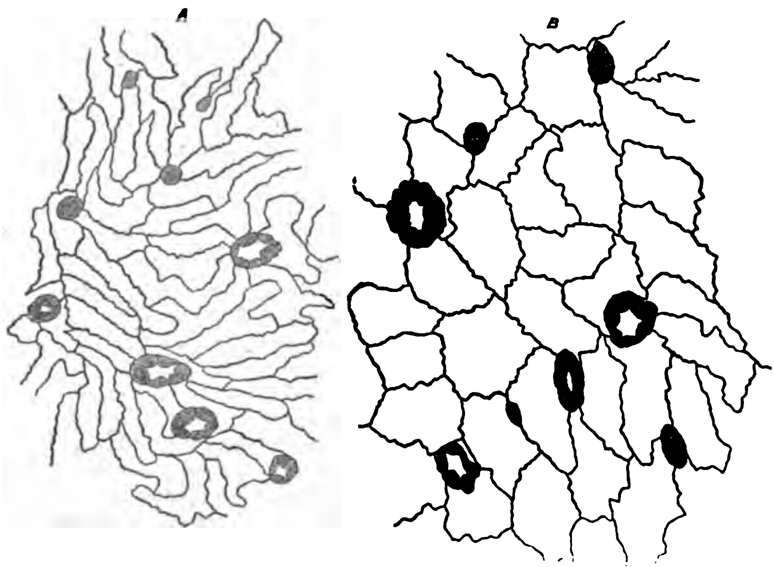
means of true stomata, *i.e.*, vertical lymphatic channels, lined by a special layer of endothelium, and leading into the lumen of a superficial lymphatic vessel, or (*b*) by means of small holes,—discontinuities between the surface-endothelium of the serous membrane, leading into a superficial simple lymphatic lacuna. By this term is understood a cavity lined only on one side by endothelium. Such a cavity may be supposed to be formed by the confluence of a number of adjoining lacunæ. Both kinds of stomata are bordered on their free surface by germinating endothelial cells. The first kind is met with in great numbers upon the straight lymphatic capillaries on the peritoneal surface of the central tendon; on the abovementioned excavations and sinuses of the lymphatic capillaries of the peritoneal serosa of the central tendon; and on the lymphatic capillaries and lymph sinuses in the omentum and pleura mediastini of all animals. These stomata are less numerous on the lymphatic capillaries of the mesentery. The well-known stomata on the septum cisternæ lymphaticæ magnae of frogs first described by Dgoiel and

FIG. 7.

Silver preparation of the peritoneal surface of the centrum tendineum of the diaphragm of rabbit.

t, Endothelium covering the serosa over the tendon-bundles. *s*, Stomata over the straight lymphatics, *l*. —Magn. × 160.

FIG. 8.



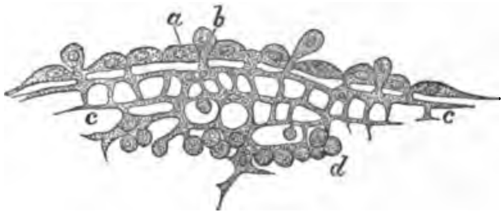
Silver-stained preparation of the septum cisternæ of frog; showing stomata.
A, Viewed from the peritoneal surface. B, Viewed from the cisterna.—Magn. × about 160.

Schweigger-Seidel, belong to this category. In contradiction to the assertion of these authors it must be remarked that the stomata in question represent vertical lymphatic canals, lined by a special layer of more or less polyhedral endothelial cells of a germinating character, and that they are not merely discontinuities between the endothelial cells having nuclei directed towards the aperture.

But there is also another kind of communication between the free surface of the serous membranes and the lymphatic system, a communication which is more indirect than the former. This takes place by means of connective-tissue corpuscles, of which the processes reach upwards to the free surface, and in the opposite direction are in continuity with those of the deeper connective-tissue corpuscles of the matrix. The lymph-canulicular system may be said to communicate freely with the surface.

To this structure I have applied the term Pseudostoma. It is met with in most serous membranes, and especially on the lymphangeal nodules and cords of the omentum, and the pleura mediastini. In the latter situations many of the germinating endothelial cells found, as already stated, on the surface of these lymphatic structures, are seen to bud directly from the pseudostomatous cells. This process plays a very important part in inflammation of the serous membranes, as will be shown hereafter.

FIG. 9.



From a fresh preparation of oedematous pleura mediastini of cat, representing a lymphatic cord in profile.

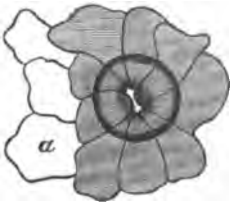
a, Germinating endothelium of the free surface. *b*, Pseudostomatous cells. *c*, Matrix of the cord. *d*, Lymph corpuscles.—Magn. × 300.

7. *Development of Lymphatic Capillaries in the Serous Membranes.*

Lymphatic capillaries may be observed in development in the normal omentum of middle-sized rabbits, and in the mesogastrium of frogs. In both instances they develop by vacuolation of connective-tissue corpuscles, which are thus converted into vesicles (*see* Fig. 11). The wall of these vesicles is at a later stage differentiated into endothelial plates. In the frog these vesicles possess at an early stage of development a ciliated lining.

By the lengthening and eventual confluence of such endothelial vesicles true lymphatic tubes are formed, the wall of which consists of a single layer of endothelial plates. When a cell, representing a pseudostoma, is converted into an endothelial vesicle, which opens freely on the surface, a true stoma is formed (*see* Fig. 10).

Fig. 10.



From a preparation of the pleural surface of centrum tendineum of guineapig.—Magn. × 160.

Showing a vacuolated cell forming a stoma by having opened itself towards the general surface.

8. *Development of Capillary Blood-vessels in the Serous Membranes.*

As has been already stated, in some serous membranes there is a constant growth and development of lymphatic nodules and cords, which after a certain period, possess a special system of capillary blood-vessels, the mode of development of which is as follows: The connective-tissue cells representing the stroma of these lymphatic structures are in direct continuity with the endothelial wall of existing capillary

vessels ; by the vacuolation of these cells, and by the eventual coalescence of the lumen of the vessel with the cavity of the vacuole, the capillary

Fig. 11.

From a preparation of the mesentery of a monkey suffering from chronic peritonitis.
a–a, Different stages of vacuolation of cells, in order to form lymphatic vessels. —Magn. × 240, *see* p. 11.

vessel enlarges, after which the protoplasmic wall of the vacuolated cells differentiates into endothelial plates.

B. *Pathological Conditions.*

1. *The Changes of the Superficial Endothelium.*—(*a*) When severe acute peritonitis is produced in a rabbit, guineapig, dog, or cat, by the introduction, *e.g.* of ammonia, of a solution of iodine in hydro-iodic acid, or of toxic pyæmic liquids (which last prove fatal in from 12 to 48 hours), into the peritoneal cavity, the mesentery, intestinal serosa, omentum, and the peritoneum of the centrum tendineum are seen to be extraordinarily hyperæmic, if examined during the first 24 or 48 hours. The abdominal cavity contains mostly, but not always, a greater or smaller quantity of sanguinolent fluid, with abundant separation of fibrin. In such cases, the endothelium of the surface is in great part loosened and detached, and the liquid contains an abundance of isolated membranous shreds composed of endothelial cells. Many of the endothelial cells, both those found free in the liquid and those still on the peritoneum, appear larger than usual, as if swollen, and their protoplasm is occupied by granules of various sizes. If the fresh membrane is examined microscopically, it may be seen that around those parts which have become deprived of their endothelium, the individual endothelial cells are distinctly granular, even in the surface view.

A further important fact is that the nuclei of the endothelial cells exhibit distinct appearances of division, and this sometimes very extensively. We not only find in the liquid a number of flat endothelial cells, in which the nucleus presents the most varied aspects of division, but in other places, such as the centrum tendineum and mesentery, we

see appearances quite different from those observed in the healthy condition ; thus, for example, on the endothelium, which covers the peritoneal side of that portion of the serosa which lies upon the tracts of tendons, and on which, as we have shown, germination is not observed in the normal condition, there is an active alteration of the nuclei over extensive spaces, from simple constriction to division into two or three small nuclei. In the case of the omentum it is more difficult to give a decided opinion as to alteration, for here extensive germination goes on in the normal condition.

Should, however, the inflammation be less intense, *e.g.* in the case of a peritonitis consequent on the entrance of air to the peritoneum, or of a peritonitis induced by the insertion of threads, or small solid bodies of starch (1–2 c.c. of a a tolerably concentrated mixture of starch and water), of Berlin blue (5–10 c.c. of 5 per cent. solution), of oil, or oil and starch—in such cases, we obtain an appearance somewhat different from the preceding. Here, indeed, there may be seen, after 24 or 48 hours, or later, isolated detached endothelial plates in the exudation, but the peritoneum exhibits only a few places where the endothelium is loosened or has disappeared. In silver-stained preparations the strongly coloured endothelial cells are seen to be granular and somewhat swollen in diameter, the nucleus has become more prominent, in short, they possess more the appearance of epithelium ; the nucleus of many of the cells is in process of division. On the omentum, and especially on the fenestrated portion, polyhedral endothelial cells whose nuclei are in process of division may be easily recognised. What is most worthy of observation is, that where germinating endothelium was observed in the normal condition a very active germination has now taken place. It extends over the abdominal surface of the centrum tendineum, as well as over the pseudo-stomata and stomata of the omentum and the mesentery. In some places the germination of the endothelium is of remarkable extent. Bud-like processes occur, which consist of young endothelial cells, and the cells so proliferating arrange themselves into cords which stretch freely over the surface. In the exudation we find a number of cells, which by their size, their granulation, and their nucleus, are sharply distinguished from the small pale blood or lymph-corpuscles. In consideration of what has been already stated, we may, I think, be allowed to regard the corpuscles, resembling endothelial cells, which occur in the exudation, as the products of the endothelium. Besides, there can be no doubt that a large number of small pale cells found in the exudation, originate by the division of the others, for on the warm stage, amœboid movements and division are observed in the large cells, which have a constricted or double nucleus.

There are intermediate stages between the forms first described and those seen in acute peritonitis of more moderate degree, just as there is a complete gradation in acute peritonitis itself between the severest degree and the mildest ; and this depends on a variety of circumstances, such as the intensity and extent of the irritation, the kind of animal observed, and other particulars unnecessary to detail in this place. What we wish to show is the difference in respect to changes of the endothelium between a very acute peritonitis, with intense hyperæmia, abundant emigration of colourless blood corpuscles, and abundant thin exudation fluid, and slight acute peritonitis, with slight hyperæmia, generally limited to the omentum, peritoneum of the centrum tendineum and intestinal covering, and no marked emigration of colourless blood corpuscles. For in the latter case, an active germination of the endothelial cells takes place, limited chiefly to those parts where germination could be made out in the normal condition, namely, on the centrum tendineum around the stomata over the lymphatic capillaries of the

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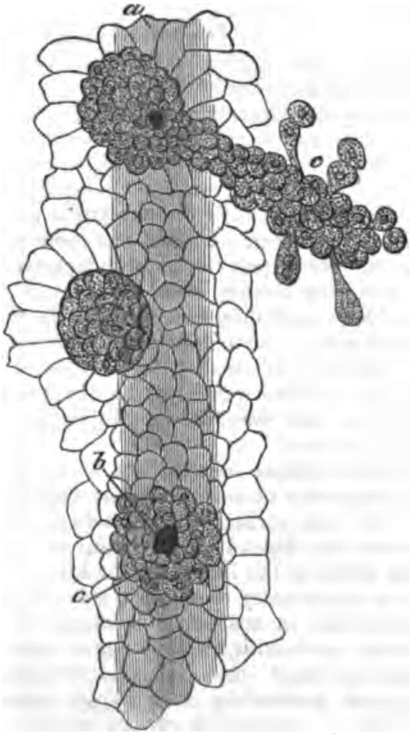
peritoneal surface, on the lymphangeal knots and cords of the omentum and of the mesentery (where we found pseudo-stomata and true stomata in numbers), and lastly, on the fenestrated parts of the omentum, where isolated pseudo-stomata are seen in the normal state.

(*b*) *Chronic Peritonitis.*—The condition of limited endothelial germination is still better observed in chronic inflammation. If we tuberculise* a guineapig by the well-known method of injecting material of an indurated lymphatic gland into the abdominal cavity, germination of the endothelium is seen round the stomata, especially on the omentum, parietal peritoneum, centrum tendineum, and mesentery. The process is most intense on the omentum. Here we find, so long as the tuberculous process has not advanced extensively, active germination of the endothelium on the knots and cords already so frequently mentioned, the number and size of which have decidedly increased. Under these circumstances the true stomata can be made out in many cases much more easily than in the normal condition, both in fresh preparations and those treated with silver. Their number, compared with that of the pseudo-stomata, is decidedly smaller.

The germination of young endothelium on the fenestrated portions in the form of small buds is also very active. The centre of each little bud is represented by a protoplasmic central stalk emerging from the matrix, which corresponds in structure to a pseudo-stoma.

As has been already indicated, the germination of the endothelium

Fig. 12.



Peritoneal surface of the centrum tendineum of guineapig sufferng from artificial tuberculosis.

a, The straight lymphatics. *b*, Stomata surrounded by germinating endothelium *c*.—Magn. × 300.

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* For a detailed account of the macroscopical conditions of the affected organs, see Eleventh Report of the Medical Officer of the Privy Council.

surrounding the true stomata is also active. Not only do the endothelial cells enlarge, become distinctly granular, present nuclei in the act of division, and germinate so as to produce lymphoid cells, but this change gradually spreads to the endothelial cells of the neighbourhood, as well as to those of the vertical lymph-canals, and to those of the lymphatic capillaries into which these lymph-canals open. If we examine the abdominal surface of a diaphragm furnished with abundant nodules of tubercle, we recognise the most varied stages of development in the germination of the endothelium of the stomata, from small buds to large patches and nodules composed of polyhedral endothelial cells. In chronic inflammation there is also abundant germination of the endothelium of true stomata on the omentum.

A fact worth noticing is, that guineapigs in which tuberculosis has been induced by subcutaneous injection, or by direct injection into the blood-vessels, exhibit a marked difference from those cases in which it is induced by injection into the peritoneum. Here the tubercular process being more advanced in the peritoneum than in the internal organs (the lymphatic glands, spleen, liver, and lungs), the germination of the endothelium round the stomata or pseudostomata is the first and chief change to be observed when the tubercular process has made little progress. This is not the case when the tuberculosis has been induced subcutaneously or by the vessels, for then no marked growth of endothelium round the stomata takes place until the tuberculosis in general is very advanced.

What has been described as regards the omentum and centrum tendineum holds good of the mesentery. Where it exhibits moderately advanced tuberculous affection, the growth of the endothelium around the true stomata occurs in a very striking manner.

Precisely the same facts may be seen in the rabbit. If a few c.c. of starch and oil or starch and water are injected into the abdominal cavity of a well-nourished rabbit, and the omentum and centrum tendineum are examined four or eight weeks later, we find that the alteration of the endothelium is limited to those places where we have previously seen stomata and pseudo-stomata, the germination of endothelium being here very considerable.

Germination of the endothelium round the stomata of the mesentery and mesogastrium is frequently observed to take place in female frogs during the winter months. In these animals the septum of the cisterna lymphatica magna shows abundant germination round the stomata on the peritoneal surface, as well as of the adjoining endothelium. It may be remarked by the way that the peritoneum of the ovaries and oviducts, and of the neighbourhood of the liver, were more or less covered with false membranes.

2.—*Alteration of the Cellular Elements of the Matrix of the Serous Membranes.*—(*a*) *Acute inflammation.*—In acute inflammations of the serous membrane, produced by injecting irritating substances, such as diluted ammonia, starch, and especially certain pyæmic and septicæmic exudation liquids, into the peritoneal cavity, the omentum and mesentery often exhibit various degrees of œdema. In such œdematous membranes the lymph-canalicular system and lymphatic vessels are seen to be much dilated by plasma, and the connective-tissue corpuscles lining the lymph-canalicular system are easily recognised even in the freshly prepared membrane as swollen, granular, flattened, branched cells. When a serous membrane, *e.g.* the peritoneum of the centrum tendineum, or the omentum, has been inflamed for 48 hours, some striking changes may be observed. In the lymph-canalicular system the lacunæ are seen to be much larger and less branched than in the normal condition, the

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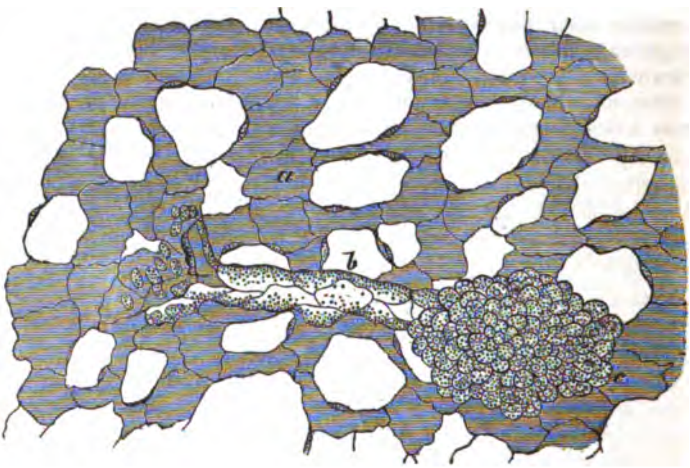
canals are wider, and a few migratory cells are found; the connective-tissue corpuscles are more granular and their nuclei constricted. In some places a still greater alteration may be seen, where the connective-tissue cells of the lymph canalicular system have undergone complete division.

(*b*) *Chronic inflammation*.—In chronic inflammation these changes are well marked. In guineapigs, in which artificial tuberculosis has been induced, the alteration of the connective cells in the matrix of the

Fig. 13.



Silver preparation of the omentum of guineapig suffering from artificial tuberculosis.
a, Trabeculæ of fenestrated omentum. *b*, A freely projecting villus.
c, Its top covered with germinating endothelium.—Magn. × 300, *see* p. 17.

serous membranes is well seen. The connective-tissue corpuscles lining the lymph-canalicular system appear to have undergone very rapid

Fig. 14.

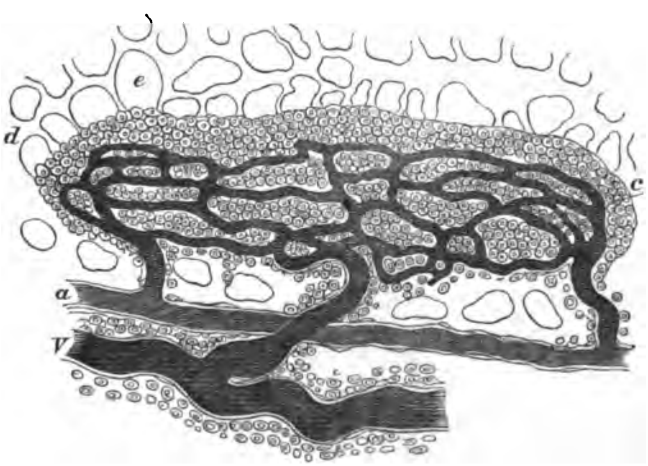
From the mesentery of a monkey suffering from chronic peritonitis, representing a morbid projection.
a, Its peduncle. *b*, Its top covered with germinating endothelium.
A vacuolated cell of its matrix. *d* Lymphoid corpuscle.—Magn. × 400, *see* p. 1 .

division; they are in many places crowded together and less branched, and exhibit the aspect of an endothelium. By such germination regular patches and nodules may be formed. As might be expected, all the lymphangeal structures we have previously mentioned increase in size by the germination of the connective-tissue cells constituting their matrix; and such structures are formed in chronic inflammation in the same way as they are formed in the normal condition, but in some cases to an enormous extent. In some animals the omentum, the *peritoneum parietale* and the mesentery are seen to be covered with papillary or villous projections, which are sometimes attached to a large lymphangeal cord or nodule of the matrix, but sometimes spring from a thin part of the membrane. These papillæ or villi are generally covered in some places with germinating endothelium, and are either a single outgrowth of a pre-existing lymphangeal nodule or cord, or originate from a pseudo-stomatous cell, which has undergone rapid germination, and has carried with it the surrounding zone of endothelial cells as a covering (*see* Figs. 13 and 14).

3.—*The Blood Vessels and Lymphatic Vessels.*—In chronic inflammation there is a very extensive new formation of blood capillaries and lymphatic capillaries. This occurs in consequence of the newly-formed lymphangeal nodules becoming supplied with their special vessels.

The mode in which capillary blood-vessels and lymphatics are formed in chronically inflamed serous membranes is precisely the same as in the normal condition.

FIG. 15.



From the fenestrated portion of an injected omentum of a guinea-pig suffering from slight artificial tuberculosis.

a, Arteries. *b*, Veins. *c*, Capillary blood vessels. *d*, Fenestrated membrane. *e*, Freely projecting lymphatic nodule.

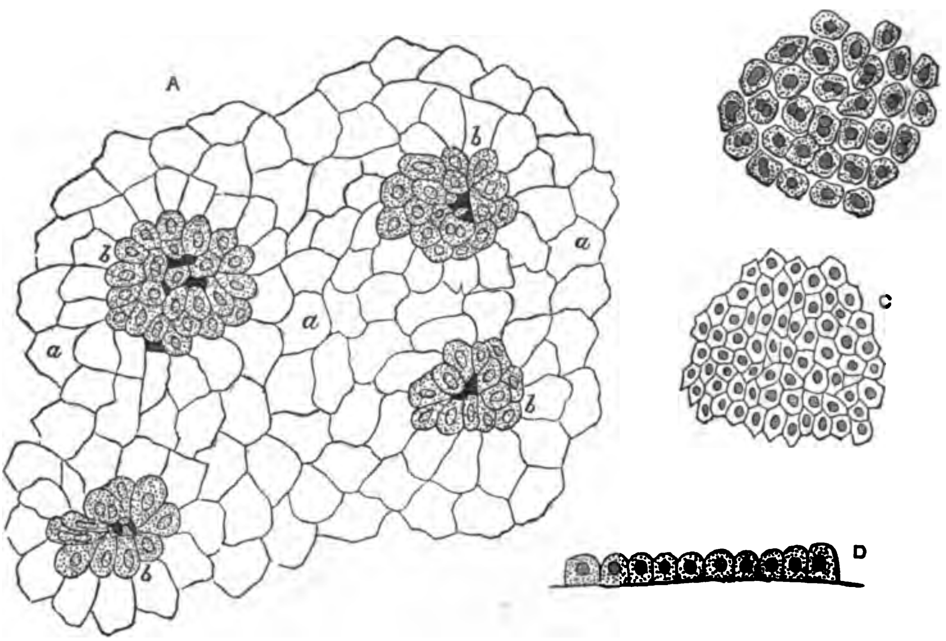
Finally, it may be stated that there is in some cases an extensive formation of endolymphangeal nodules in pre-existing lymphatic vessels.

Part II.—Lymphatic System of the Lungs.

A. *Normal Anatomy.*

The endothelium of the surface of the lungs consists, in the normal condition, of polyhedral cells (not flattened as commonly described) arranged in a single layer. This is well seen in guineapigs, less distinctly in rabbits, rats, dogs, and cats. If the lung is not distended, the endothelium of the surface very much resembles an epithelium, the cells being polyhedral, or in the form of short columns; they are

Fig. I.



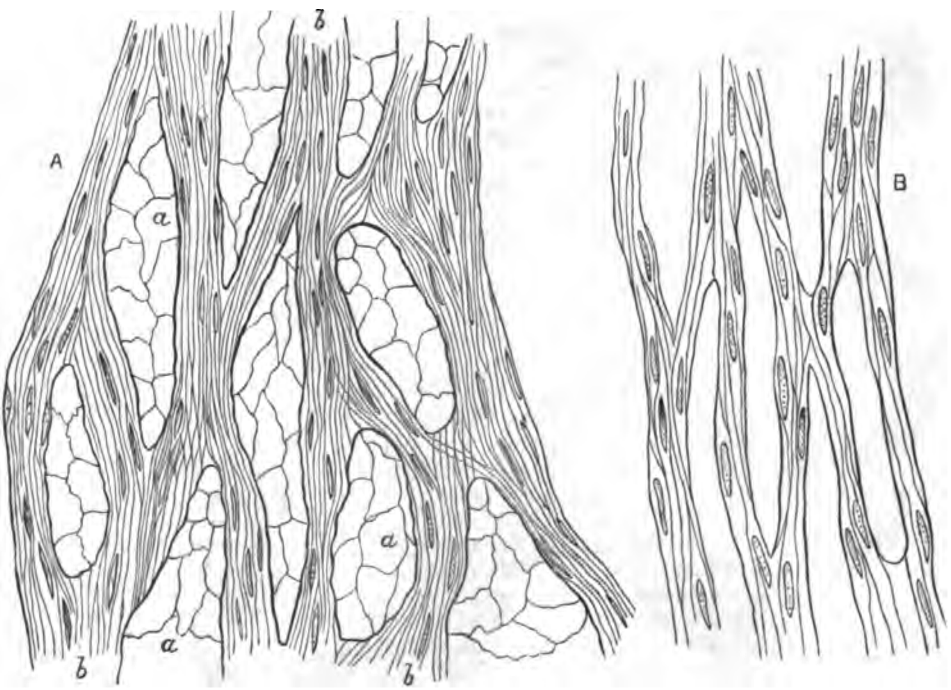
A, Surface view of the endothelium of the pulmonary pleura of a rabbit in the condition of chronic pleuritis, *see* p. 21.
a, General flattened endothelium. *b*, Germinating endothelium around stomata.
B, Endothelium of the pulmonary pleura of a guineapig suffering from artificial tuberculosis, the endothelium being viewed from above.
C, Endothelium of a normal pulmonary pleura of guineapig, viewed from above.
D, The same endothelium viewed in profile.—Magn. power, 300.

markedly granular, and have distinct nuclei. Even in the moderately distended lung, the endothelium of the pleura pulmonum is by no means of the same morphological character as that on the costal pleura. Between the endothelium of the one and that of the other organ there exists the same difference as between that of the ovary and that of the peritoneum—the one consisting of polyhedral, or shortly columnar, granular cells with very marked nuclei, the other of very flattened, almost hyaline, endothelial plates.

The pleura pulmonum is a very thin connective-tissue membrane, provided, like other serous membranes, with a rich network of elastic fibres. In the lungs of the rat, rabbit, cat, and dog the pleura pulmonum seems to consist, for the most part, of elastic networks. In the matrix, there is generally one layer of flattened connective-tissue corpuscles to be found.

Beneath the proper pleural membrane there exists, in the guineapig, a membrane which consists of non-striated muscular fibres, arranged in bundles which form a meshwork. In the normal condition the bundles are relatively thin, and the meshwork which they form has elongated large meshes. In the distended lung the meshes are of a much greater diameter than in the collapsed lung; in the latter they form a more continuous membrane. The muscular bundles have, in general, a radiating direction from the apex towards the basis of the lung; and it is further to be noted that they are most abundant on the external surface, viz., that directed towards the anterior wall of the chest, and the internal surface, viz., that directed towards the mediastinum; whereas on the posterior surface the bundles are scanty, and become more and more so the nearer the vertebral column is approached. This distribution of the muscular tissue is therefore in perfect agreement with the proportion in which the different parts of the lung participate in the respiratory movement, the fibres being most richly distributed over those parts of the pulmonary surface which are subject to the greatest extent of excursions, and *vice versâ*. In rats and rabbits, as well as in cats and dogs, bundles of unstriped muscular fibres occur sparingly; at any rate there are none on the posterior surface of the lung of these animals. As soon as the superficial parts of the lung

FIG. II.



A, Meshwork of unstriped muscles in the pulmonary pleura of a guineapig suffering from artificial tuberculosis:
a, Intermuscular lymph spaces lined by endothelium. *b*, Muscular trabeculæ.—Magn. × 300.
B, Meshwork of unstriped muscles in the normal pulmonary pleura of guineapig.—Magn. × 300.

become the seat of a chronic inflammatory process (*e.g.* tuberculosis, chronic pneumonia), the muscular bundles increase in breadth and number to such a degree, that they form a continuous membrane, chiefly in those parts of the surface which correspond to the diseased portions of the lung.

FIG. III.

Injected subpleural lymphatic vessels of a guineapig's lung.

a, Main branches provided with valves. *b*, Branches emerging from the depth, *i.e.*, the interalveolar tissue.—Magn. × 90. *See* p. 21.

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1. *Subpleural lymphatics.*—The meshes of the muscular membrane of the lung of guineapigs are lined by a single layer of flattened endothelial cells, constituting, in fact, a communicating system of lymphatic sinuses. I call this system of lymphatics the *intermuscular or pleural lymphatics.* In the distended lung of the guineapig, these pleural lympathic sinuses are seen to be covered by hardly anything but the endothelium of the pleural cavity, between which and the cavities of those sinuses a free communication exists by means of true stomata; so that the endothelium lining the sinuses is here directly continuous with that of the pleural surface. In every case of chronic pleuritis induced by injecting irritating substances (such as products of acute and chronic pyæmic processes, products of indurated lymphatic glands), an active germination of the endothelium around those stomata takes place (*see* Fig. I.). This germination extends not only to the endothelium of the neighbouring parts of the pleural surface, but also to the endothelium of the intermuscular lymphatic sinuses. The relation between the cells of the membrana propria of the pleura pulmonum and the endothelium of the surface, is similar to that already described by me in other serous membranes, the cells of the *propria* throwing out processes, which project between the endothelial elements of the free surface, thus forming pseudostomata. The pleural lymphatics stand in communication with lymphatic tubes, which lie in grooves, the arrangement of which corresponds with that of the most superficial groups of alveoli of the lung. These may be called the *subpleural lymphatics;* they are provided with valves, and form a network of anastomosing lymphatic vessels. The larger trunks run along the ligamenta pulmonum towards the root of the lung. This system of lympathic vessels is best developed in the lung of the dog, in which it has been described by Wywodzoff; it is also well developed in the lungs of rabbits and cats. It receives lymphatic branches, which take their origin between the alveoli of the superficial portions of the lung. The mode of origin of these interalveolar lymphatics is that already described in my report on the serous membranes. The septa of the alveoli contain branched connective-tissue corpuscles; the spaces in which these cells lie, forming the lymphcanalicular system, open into the cavities of the interalveolar lymphatics, with the endothelium of which the cells of the lymphcanalicular system are in direct continuity.

2. *Perivascular lymphatics.*—Besides the system of subpleural lymphatics, the lung contains two other systems; of which one takes its origin in the alveolar septa from branched cells exactly like those previously referred to. The lymphatic capillaries of this system lead into vessels that accompany the branches of the pulmonary artery and vein; they run either in the adventitia of these vessels in twos or threes, anastomosing with each other, or the blood-vessel is entirely, or only half invaginated in a lymphatic vessel (*see* Fig. IV.). The branched cells of the alveolar septa, from which the capillaries of this system of lymphatics (which we will call the *perivascular lymphatics*) originate, have an important relation to the epithelium of the alveoli; for they send a process, or a greater or less portion of their body, between the epithelial cells into the cavities of the alveoli. These represent pseudostomata, such as I have described for the serous membranes. As these branched cells have a corresponding lymphcanalicular system, it is easy to understand why Sikorski, in his experiments, found that carmine entered freely from the cavities of the alveoli into the interalveolar lymphatics. But there is no other communication between the cavities of the alveoli and the lymphatics than by means of these pseudostomata. It can be easily understood that the pseudostomatous canals (viz. the canal in which lies the process of a cell

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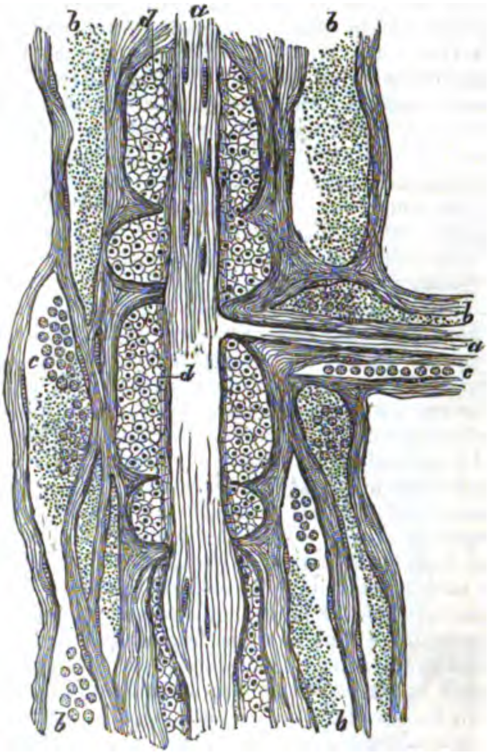
projecting freely into the cavity of an alveolus, and the lymphcanalicular system, in which the interalveolar branched cells lie) may become occasionally distended, *e.g.* in inflammation, by exudation, or by migratory

FIG. IV.



From a vertical section through the lung of a guineapig suffering slightly from artificial tuberculosis, *see* p. 21.

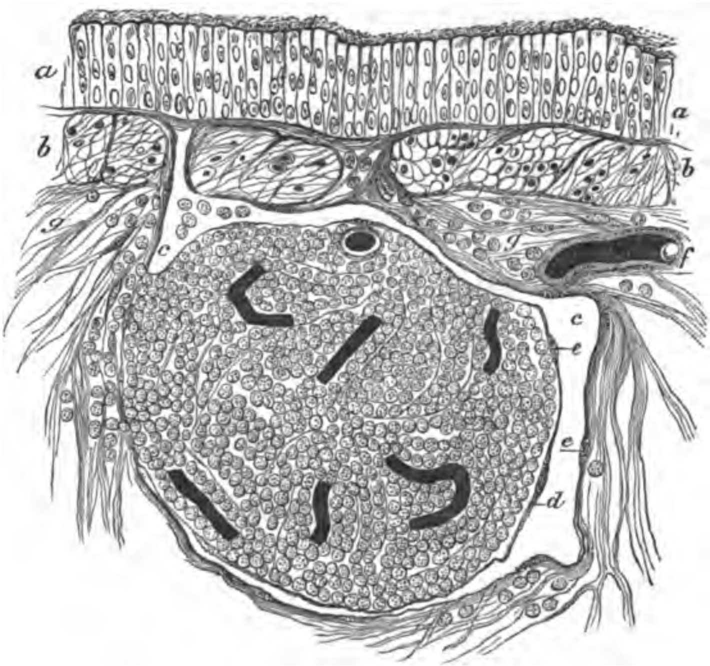
a, Branch of pulmonary artery. *b*. Perivascular lymph-spaces, containing granular material and lymph-corpuscles *c*. *d*, Transversely cut muscular bundles.—Magn. × 160.

cells. In fact, it must be assumed that cells, such as are produced by catarrhal inflammation of the air-passages, migrate from the cavities of the alveoli into the interalveolar lymphcanalicular system through those pseudostomata; and the same assumption must be made for the well-known large granular mucous corpuscles, which in many lungs contain carbon particles, inasmuch as similar cells are found in the interalveolar tissue.

3. *Peribronchial lymphatics.*—The third system of lymphatics is composed of lymphatic vessels which are chiefly distributed in the adventitia of the bronchi. I shall therefore call it the system of ***peribronchial lymphatics.*** The vessels of this system are usually distributed around the bronchi, anastomosing with each other, and especially with the perivascular lymphatics. The vessels of the peribronchial system take up capillaries, which originate in the mucous membrane of the bronchi and penetrate through the tunica muscularis of the bronchi. These capillary branches originate in the usual way; *i.e.* their wall is continuous with the branched cells of the mucosa, which cells in turn penetrate, as a

nucleated reticulum, between the epithelial cells of the bronchus, and project on its free surface. From this it may be understood how particles can penetrate from the cavity of a bronchus into the peribronchial lymphatics, as in the experiments of Sikorski. The lymphatics are always most numerous on that side of a bronchus which is directed towards a branch of the pulmonary artery. In the course of each bronchus, especially those that possess only a thin muscular tunic and no trace of cartilage, there are generally several vascular lymph-follicles to be met with, which are placed in continuity with the endothelial wall of a lymphatic vessel, in such a manner that they are surrounded by that

Fig. V.



From a longitudinal section through the wall of a bronchus of a guineapig's lung.
a, Ciliated epithelium. *b*, Muscular coat. *c*, Lymph-sinus surrounding an injected lymphatic follicle *d*. *e*, Its endothelium. *f*, Injected blood vessels. *g* Lymph corpuscles. —Magn. × 300.

lymphatic vessel, in the same way as the lymph-follicles of Peyer's patches are by their lymph-sinuses. These follicles, already seen by Dr. Burdon Sanderson, extend up to the tunica muscularis; in some instances they are to be traced through this latter into the mucosa. They always lie in the wall of a lymphatic vessel, between the bronchus and the accompanying branch of the pulmonary artery. They are of different sizes, and are generally spherical or elliptical; sometimes they represent merely a cord-like thickening of the wall of the lymphatic vessel. In the lung of the guineapig these peri-lymphangeal follicles are very numerous; they are not so numerous in rabbits. It can be proved that a constant growth and reproduction of these follicles is going on. The lymphatic vessels of the two last-mentioned systems, anastomose with each other in the ligaments of the lung, and finally enter the bronchial lymphatic glands.

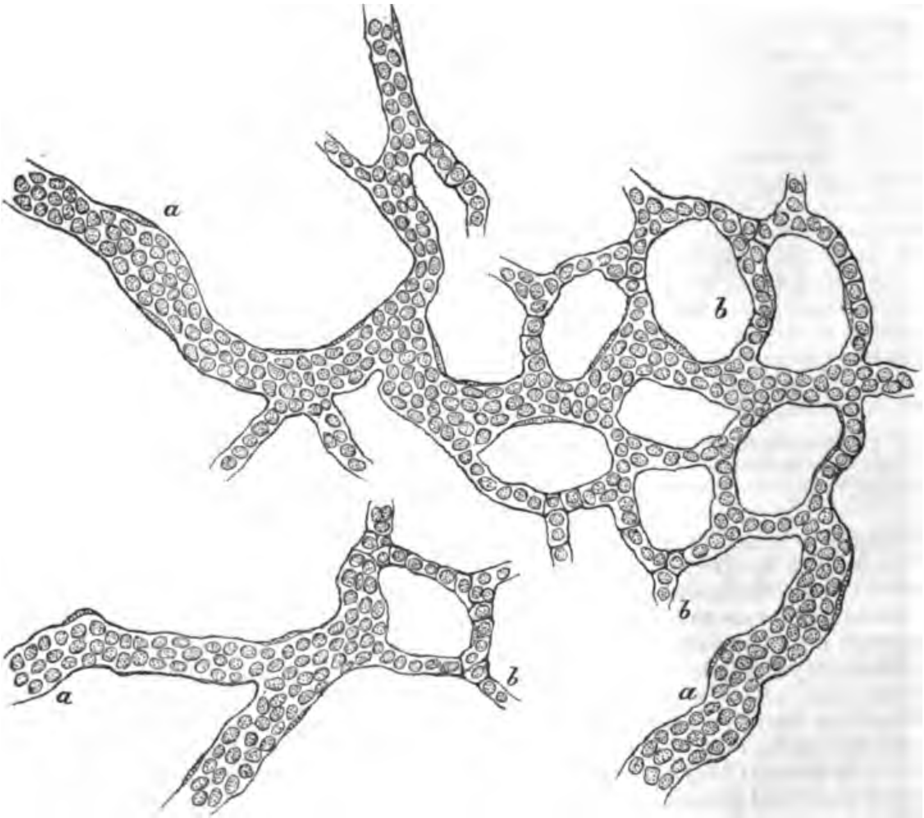
B. *Pathological Conditions.*

I have already mentioned the germination of the endothelium of the surface, and the hypertrophy of the muscles, in chronic diseases of the lung.

In many chronic inflammatory processes of the lung (chronic pyæmia, artificial tuberculosis, chronic pneumonia) the pleura pulmonum becomes the seat of nodules of various sizes and shapes. Generally they are more or less round, and correspond in position to those superficial portions of the lung which have become the seat of an inflammatory process. These nodules of the pleura are due to a very rapid germination of the branched connective-tissue corpuscles, simultaneously with an increase of fibrous connective-tissue, this latter fact being very obvious when the nodules have reached a certain age. As long as they are small, they show merely an abundance of cellular elements; in their later stages they become richly supplied with capillary blood-vessels.

Lungs of guineapigs that are far advanced in the process of artificial tuberculosis (*i.e.* where the bronchial glands have already become the seat of cheesy deposits) show superficial nodules, which are in direct

Fig. VI.



Subpleural lymphatics of a guineapig suffering from artificial tuberculosis, *see* p. 25.

***a*, Main branches. *b*, Interalveolar branches; both are filled with lymph-corpuscles; in some places the lymphatics are in the act of becoming converted into cords of adenoid tissue.—Magn. × 300.**

continuity with the subpleural lymphatics. In horizontal sections through such portions of the lung, one finds these lymphatics filled with lymph-corpuscles, while at a later period they are occupied by an adenoid reticulum, the meshes of which contain lymph-corpuscles, and which is in direct continuity with the endothelium of the lymphatic tubes (*see* Fig. VI.). The nodules themselves represent a network of cords, which very much resembles adenoid tissue. The meshes of this network of trabeculæ are the alveoli, which, at an early period, contain a few lymphoid corpuscles, while the epithelium is, at the same time, in a state of germination, the individual cells being swollen and the nucleus in a state of division. At a later period the alveoli are filled with small lymphoid corpuscles, while the epithelium of the alveoli is no longer to be distinguished as such. The blood-capillaries belonging to these alveoli have undergone some remarkable changes, of which I shall speak at length afterwards; at present I will only mention that at a later period they are no longer permeable for the blood. These interalveolar trabeculæ of adenoid tissue, forming the framework of the superficial nodules, are developed from the branched connective-tissue corpuscles of the alveolar septa. The same process extends to the subpleural lymphatics, originating from these interalveolar connective-tissue corpuscles, in such a way that these lymphatics become converted into cords of adenoid tissue connected with their endothelium. Consequently these lymphatics become converted into endo-lymphangeal cords.

In the same stage of the process of artificial tuberculosis characterized as above stated by the presence of cheesy deposits in the bronchial glands, two kinds of morbid structure can be distinguished by the naked eye on the surface of the lungs :—

(*a*) Translucent structures of a circular or irregular shape, sometimes projecting slightly above the surface, generally isolated, but in some instances confluent, so as to form patches. The smallest are of the size of the head of a small pin ; some of them are three, four, or several times as large. In some lungs only the large structures are to be found; the larger kind have generally a yellowish centre.

(*b*) Opaque patches of considerable diameter projecting above the surface of the lung, some of them relatively very large (about $\frac{1}{8}$ to $\frac{1}{10}$ of an inch), quite white, and very firm. On sections through the lung one finds that the first kind of structures correspond with cords provided with lateral nodular swellings, which accompany the branches of the pulmonary artery and vein. The second kind of structures correspond with nodules and patches which are irregularly distributed in the tissue of the lung. On microscopical examination it is seen that the first kind of structures are perivascular cords of adenoid tissue, representing the follicular tissue which is found in the walls of the peribronchial lymphatics in the normal condition (*see* Fig. VII.). Many of these perivascular cords or nodules are supplied with a system of capillary blood vessels. The second kind of nodules, or patches, are seen to consist, on microscopical examination, of a framework of trabeculæ which corresponds to the interalveolar tissue ; they represent trabeculæ of adenoid tissue which are in continuity with the perivascular cords first mentioned. The meshes of this network are more or less filled by cells lying in the spaces that were previously the cavities of the alveoli. The question arises, How do these two kinds of morbid structures develop, and what is their ultimate fate ?

If one studies sections of lungs that possess very few of the first kind of cords and nodules, one comes across a number of the lymphatic vessels that accompany the branches of the pulmonary artery, containing more or less numerous lymph-corpuscles. In addition to those

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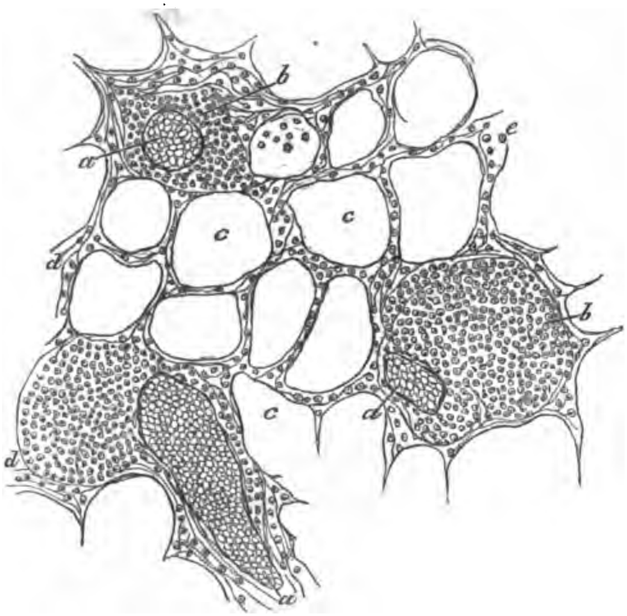
just mentioned, lymphatic vessels may be found the endothelium of which is in continuity with a thin short cord of adenoid tissue that stretches along the outer wall of the lymphatic, or (as may be seen in some places) projects into its cavity, thus connecting the two endothelial walls of the lymphatic ; in other words, we have here a peri- as well as an endo-lymphangeal growth of adenoid tissue, connected with the

Fig. VII.



From a vertical section through the lung of a guineapig suffering from artificia tuberculosis. *a*, Blood vessels in transverse section filled with blood. *b*, Perivascular cords of adenoid tissue. *d*, Nodular swelling of the latter. *c* Alveoli. *e*, Interalveolar tissue.—Magn. × 60, *see* p. 25.

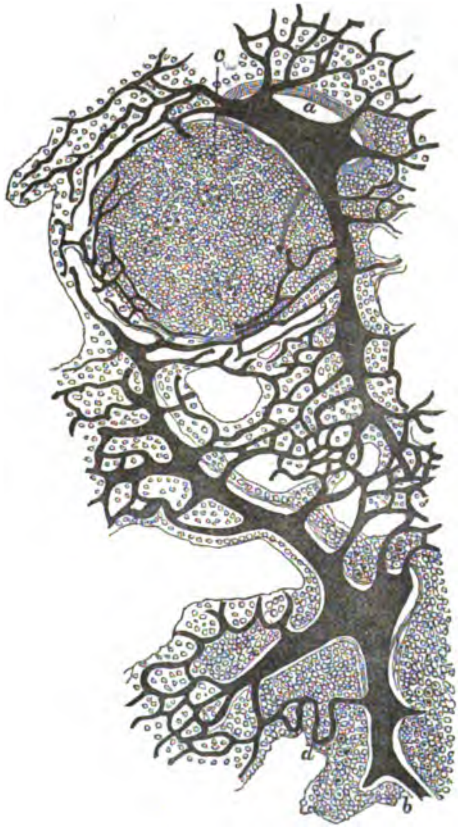
endothelium of the lymphatic. From what I have shown in the case of the serous membranes, there can be little doubt that the above-mentioned tuberculous cords of adenoid tissue accompanying the blood-vessels are in reality only peri- or endo-lymphangeal outgrowths of the endothelium of the lymphatics. It is important to state that, at the same time, the follicles of the bronchial adventitia increase in size, and also that a peri-lymphangeal new growth takes place on the peribronchial lymphatics. From the study of the normal lung, it can be ascertained that all the large branches of blood-vessels are not accompanied by lymphatics, nor even a single branch along its whole length, but that in some places they are only surrounded by branched connective-tissue corpuscles, which may be said to belong to their adventitia. In a particular case, it cannot be determined whether a certain tubercular cord has developed by the increase of these adventitial cells, or whether it has developed from the endothelium of a lymphatic, either as a peri- or endo-lymphangeal cord ; for the fully developed cords have the same relation to the blood-vessels as if they had developed in their adventitia.

I have already mentioned that the growth of adenoid tissue in the branches of the subpleural lymphatics extends to the connective-tissue corpuscles between the alveoli. Exactly in the same way we see the perivascular adenoid cords spreading between the alveoli; that is to

say, the perilymphangeal growth of tracts of adenoid tissue extends from the lymphatics to the interalveolar branched cells, with which the endothelium of the former is in direct continuity.

The first points at which the tubercular perivascular cords of adenoid tissue make their appearance are the ultimate branches of the pulmonary artery and vein, whence they spread along the lymphatics towards the

Fig. VIII.



From a section through the lung of a tuberculous guineapig.
a, Branch of pulmonary artery. *b*, Branch of pulmonary vein. *c*, Tubercular nodule. *d*, Tubercular cords.—Magn. × 60.

larger branches as well as towards the interalveolar branched cells. In general the growth in the first direction (that is, towards the larger branches) goes on much more abundantly and rapidly than in the other direction.

The following important facts are constantly met with in the tuberculous lungs of guineapigs:—The ultimate branches of the pulmonary artery show a germination of their endothelium, which is already recognizable in the earlier stages of the disease, at a time when perivascular cords are only rarely to be found. If the process advances, the germination of that endothelium reaches such a degree that the cavities of the blood-vessels are almost filled with its products, only a very narrow central canal being left free. In later stages, the tunica media of the smaller and middle-sized vessels, that are provided with perivascular cords, becomes very much thickened, and splits into laminæ,

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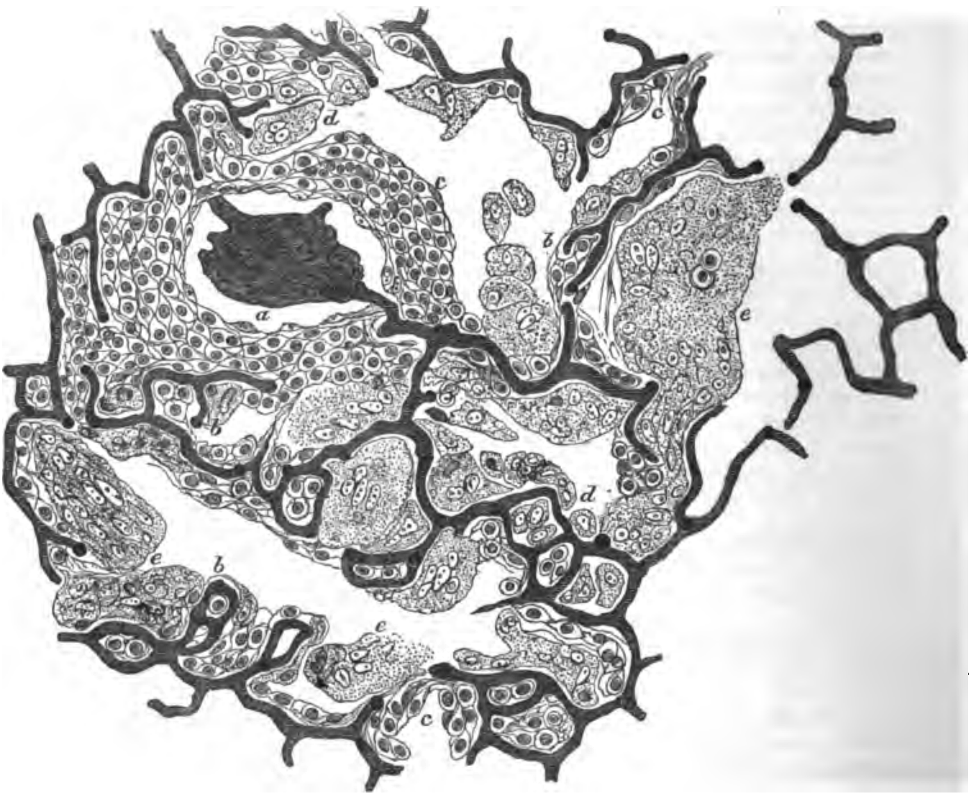
between which lie accumulated lymphoid cells, either free or contained in a reticulum. In many places it can be shown that the adenoid tissue of the perivascular cords gradually grows towards the cavities of the vessels, and finally assumes the whole portion of the vessel into its substance. The chief fact of importance, however, is that the capillary blood-vessels of those interalveolar trabeculæ, into which the perivascular cords have penetrated, have become converted into solid nucleated bands and threads, which are in continuity with the surrounding reticulum. These threads, although they appear solid, must be taken as still permeable by fluid substances; for in lungs, the pulmonary artery of which had been previously injected with a cold solution of Berlin blue, the cavity of many of the capillaries in the neighbourhood of these interalveolar trabeculæ stops short, but the injecting material can be traced into the nucleated filaments which enter these trabeculæ. From the study of a great number of specimens taken from lungs in different stages of the process of artificial tuberculosis, I have reason to believe that the first parts which undergo inflammatory changes are the ultimate branches of the pulmonary artery and the capillaries next to them, and that the morbid process extends from them to the corresponding lymphatics.

I have already mentioned that where the alveolar septa become

Fig. IX.



From the same lung as Fig. VIII.

a, Branch of pulmonary artery. *b*, Capillary blood vessels surrounding the alveoli. *c*, Perivascular adenoid tissue. *d*, Epithelium of alveoli. *e*, Giant-cells, having originated by the fusion of several epithelial cells.—Magn. × 400, *see* p. 29.

thickened, the epithelium of the alveoli becomes gradually changed, so as completely to fill the cavities of the alveoli. By this means nodular or patch-like structures are formed, which may be called secondary patches. It may be said, in general, that the epithelial cells germinate: they enlarge; their nuclei divide; and then the cells themselves divide. In many alveoli there appear, besides isolated epithelial cells, with or without carbon particles in their substance, numerous small lymphoid corpuscles. In some of the alveoli the enlarged epithelial cells become fused together to one large mass of granular protoplasm, which contains a number of nuclei in its periphery; this represents, in the true sense of the term, a "giant cell" (*see* Fig. IX.). We may therefore say that, at an early period, these patches consist of trabeculæ, which represent the thickened interalveolar septa and their meshes (the alveoli), and that the latter are filled either with small cells or with giant cells, or rather with multinuclear protoplasmic cylindrical masses. These secondary patches gradually increase in size, by the extension of the adenoid metamorphosis of the alveolar septa, and the changes of the capillary blood-vessels, indicated above.

A perivascular cord may become furnished with a number of lateral nodules of adenoid tissue from the assumption, by adenoid interalveolar cords, of the contents of alveolar cavities into their own tissue. Where, however, the alveolar cavities contain giant cells, other remarkable changes take place. These are as follows:—The cylinders of multinuclear protoplasm grow and divide into a number of giant cells, which gradually become converted into a tissue to a certain extent resembling adenoid tissue, but differing from it in many respects. Thus the giant cells give origin to a more or less regular network of nucleated cells, which, consisting at first of granular substance, soon assumes the appearance of a more or less distinct fibrillar substance; in their meshes lie only a limited number of lymphoid cells. This tissue spreads very rapidly, and finally undergoes, from the centre outwards, a fibrous degeneration, which becomes the seat of cheesy deposits.

Different lungs are somewhat different in this latter respect. In some cases the transformation of the giant cells into a network of nucleated cells goes on very rapidly; and then the cheesy metamorphosis is also soon established. In other cases the growth of the network of nucleated cells has a very long duration, and consequently the growth of the secondary patches remains active for a long time. The network of nucleated cells is, at no period of its development, such a delicate reticulum as in the adenoid tissue, nor does it contain lymphoid corpuscles so constantly as this latter. Moreover the adenoid tissue of the perivascular cords or their lateral nodules *never becomes the seat of a fibrous or cheesy metamorphosis*. The more the lung has advanced in the process of artificial tuberculosis, the more do we find the tissue of the lung, in the neighbourhood of the primary and secondary nodules, undergoing inflammatory changes which consist in thickening of the alveolar septa, and in a granular condition of the walls of their capillary blood-vessels, the nuclei of which are in active germintion, their number being disproportionately large.

In the peripheral parts of the lung the most numerous secondary nodules are to be met with; and consequently the most numerous cheesy deposits are here to be found. I have often seen a system of large patches projecting somewhat above the surface and radiating towards the deeper parts, as the terminal branches of a minute bronchus pass towards the stem.

The secondary process extends from the terminal branches (alveoli and infundibula) to the large bronchi. In these the process becomes very marked, and consists of the following changes:—

(*a*) The epithelium germinates very abundantly, whereby the cavity may finally become almost completely plugged up by the progeny of the epithelium.

(*b*) A more important change consists in the germination of the tissue that we have designated above as pseudostomata, namely, the branched cells of the tunica mucosa that extend between the epithelial cells and the surface; this tissue grows so as to form a very rich adenoid tissue. At the same time an active growth of adenoid tissue in the walls of the peribronchial lymphatics takes place; that is to say, there is a hyperplasia (Sanderson) of the pre-existing follicles, as well as a new formation. [The most active transformation of the pseudostomatous tissue of the bronchi into adenoid tissue I have met with was in rabbits suffering from chronic pyæmia; it has been already stated that the reticulum of branched cells which stretches between the epithelial cells of the surface is better developed in rabbits than in guineapigs, in the normal condition.]

(*c*) In the large bronchi, which have become involved in the secondary process, another noteworthy change takes place, viz. the fusion of groups of the germinating epithelial cells, not only those of the free surface, but also those of the mucous glands, so as to form multinuclear protoplasmic cylinders and lumps (giant cells).

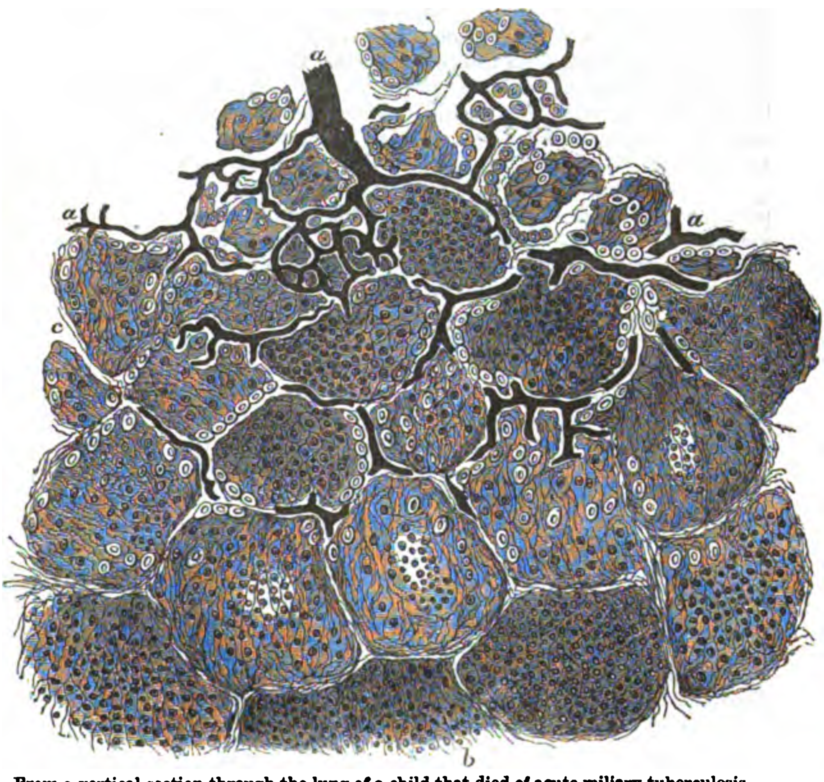
This secondary process affecting the alveoli and bronchi, which may be justly called the catarrhal pneumonic process, always accompanies artificial tuberculosis when it has extended to the interalveolar tissue; in the early stages of artificial tuberculosis, *only the perivascular lymphangeal cords are to be met with.*

If the infection has been established from the pleural cavity, the germination of the endothelium of the surface round the stomata, and the transformation of the subpleural lymphatics into cords of adenoid tissue, is the first symptom, and is followed by the appearance of perivascular adenoid cords. If, however, the lung becomes tuberculous by infection from the blood-vessels, the peritoneal cavity, or the subcutaneous tissue, the perivascular adenoid cords are the first structures that make their appearance. In lungs which have become the seat of chronic pyæmia, the first changes are to be found in the alveolar septa and alveoli, viz., the formation of patches and nodules similar to those that I have designated before as secondary; and if the process lasts long enough, those changes take place that I have designated before as primary tuberculous changes.

The opinion has been expressed (by Sanderson and Wilson Fox) that the process of artificial tuberculosis in the lungs of guineapigs resembles, in its anatomical features, the tuberculosis process in man. I will therefore examine the process that is clinically and anatomically known as acute miliary tuberculosis in man. For this purpose I shall describe the changes that I found in three series of cases of the disease in children, representing, as we shall see, three different stages of development. In the first series the lungs exhibited all the anatomical appearances of acute miliary tuberculosis. On microscopical examination it was found that the nodules were due to groups of alveoli (with the corresponding infundibula) being filled with and distended by a fibrinous material that contained granules and a few small cells; generally these

latter occupied the centre of the alveoli. The walls of the alveoli were hardly distinguishable; and the capillary vessels were not permeable, as shown by the fact that, in well-injected preparations, the injection did not penetrate into the capillaries of the alveolar septa. The alveoli next to these nodules contained the same fibrinous material; but they were not filled up by it completely; and their epithelium could be distinctly recognized, having become wholly or partially detached, the individual cells being somewhat enlarged, and some of them containing two nuclei. Here the injection material penetrated the capillary blood-vessels more or less perfectly; the alveoli of the neighbouring parts contained either a small amount of fibrinous material, besides isolated young cells, or a

Fig. X.



From a vertical section through the lung of a child that died of acute miliary tuberculosis. The figure represents about the third part of a tubercle.

a, Injected blood vessels, becoming quite impermeable towards the centre of the tubercle. *b*, Centre. *c*, Periphery of the tubercle.—Magn. × 160.

homogeneous gelatinous substance that had become stained with hæmatoxylin. The epithelium was very distinct, its cells granular. In some of the alveoli the epithelial membrane was more or less detached from the alveolar septa; the capillary blood-vessels were perfectly permeable.

In the second series of acute cases of miliary tuberculosis, in which the lungs did not differ in macroscopical appearance from those of the first series, but in which the process had lasted longer, the microscopical appearances were somewhat different. The nodules were seen to differ in their

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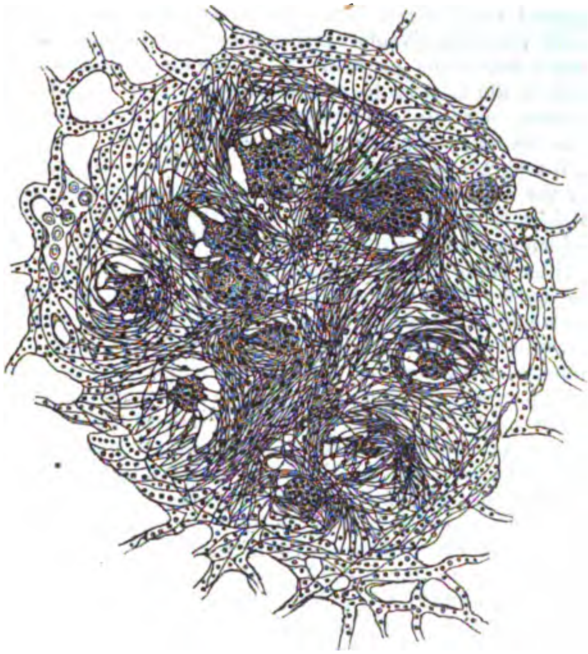
structure from those in the former series in the following respects. In some of them it was easy to recognise that they represented a number of alveoli very much distended by a fibrinous substance similar to that described above, which included granular material and a number of small cellular elements; the trabeculæ of these nodules (that is, the interalveolar tissue) were slightly thickened and contained young cells, their capillary blood-vessels being not completely permeable and not easily distinguishable. Besides these there were nodules of which only the central alveoli were in the state just mentioned; whereas in those situated more peripherally the fibrinous material could no longer be discovered, but they were filled in one or other of the following ways:— First, by spherical nucleated elements, many of which could be still recognised as epithelial cells, by their size, granulation, and nucleus, and some of which contained two nuclei. In these places the interalveolar trabeculæ were thickened in a very marked manner, exhibiting all the appearances of an infiltrated tissue, that is to say, a more or less distinct reticulum of nucleated fibres, in the meshes of which lay small lymphoid corpuscles very readily stained by logwood or carmine. Or, secondly, they were filled by one large multinucleated mass or giant cell. In the latter case the giant cell, or rather the multinuclear protoplasmic cylinder, contained the nuclei either regularly distributed in its periphery, or all crowded together in the central part of the mass. As regards the nuclei, it may be said that they stain readily; they are relatively small, sharply outlined, and contain one or two nucleoli. The protoplasm of the giant cell is tinted slightly yellowish, does not stain in hæmatoxylin, and is very regularly filled with small granules of equal size. As regards the development of these giant cells and their nuclei, I must first contradict those authors who say that they originate generally by a free-cell formation in the veins, as well as those who make them originate in lymphatic vessels; for I have followed their development from the epithelial cells of the alveoli with all possible certainty. I have been able to make out that the whole epithelial lining of an alveolus becomes fused together into one protoplasmic lump, which fills the alveolar cavity, and the nuclei of which rapidly divide, remaining, however, in their original places, viz. peripheral. What we have before us is a protoplasmic cylinder, the transverse section of which shows a peripheral ring of nuclei. But a single epithelial cell may also become transformed into a multinuclear giant cell: an epithelial cell increases rapidly in size, probably at the expense of its fellows; its protoplasm becomes enlarged as well as its nucleus, then this nucleus gives rise by cleavage, or by budding, to a number of small nuclei, so that it is transformed into a number of nuclei lying in the middle of the cell.*

Where the alveoli contain giant cells the alveolar septa are very much thickened, and are seen to consist of a tissue that contains branched and spindle-shaped cells, the substance of which has more or less the appearance of a fibrous tissue, their processes as well as their body

* I have little doubt that Klebs would be inclined to regard the very regular granulation of the giant cells previously mentioned, as being due to the presence of micrococci; such an assumption, however, could not easily be proved. It does not follow because a substance is filled very regularly with granules that these are micrococci. To such view it may be objected, first, that there a number of normal tissues that appear after hardening to be just as regularly filled with granules (*e.g.* the liver-cells of any liver hardened in spirit), and, secondly, that the resistance of these granules to acids and alkalies after hardening does not prove them to be micrococci.

being slightly fibrillar. Between these there are very few lymphoid corpuscles to be found.

Fig. XI.



From a vertical section through the lung of a child that died of acute miliary tuberculosis. The tubercle represented in this figure is of a later stage than the one in Fig. X.
The tissue surrounding the tubercle is like adenoid tissue; the original alveoli contain giant cells, which give origin to nucleated fibres.—Magn. × 50.

In a third series of lungs, which also in macroscopical aspect did not differ from the former ones, it was seen that almost all the nodules contain giant cells, corresponding to the alveolar spaces. These, however, have undergone changes which are correctly described by Schüppel and others; *i.e.* the giant cells give rise to a network of branched nucleated cells, as well as to a few spherical nucleated elements that lie in its meshes. This network grows at the expense of the giant cell, which undergoes germination at the same time. We have here what is generally called a reticular tubercle (*see* Fig. XI.). From one giant cell a number of giant cells may take their origin.

The nearer to the centre of a nodule the giant cell lies, the more extensively and quickly does a transformation of its substance take place. It becomes converted into a very dense feltwork of fibrillar tissue, the nuclei of which gradually disappear, while the tissue itself dies away, becoming firm and hard, and finally resembling a granular substance, in which fibrils can be made out very indistinctly. While the network of the nucleated cells continues to grow at the expense of the giant cells, the process of necrosis spreads gradually to the peripheral parts. In this stage of the process the thickened interalveolar trabeculæ become also comprised in, and identified with, the tissue that originated from the giant cells. In the neighbourhood of the nodules there are very numerous places where the interalveolar trabeculæ are thickened and contain numerous young cells, the epithelium of the corresponding

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alveoli being, at the same time, in a state of germination. In general the tubercular nodules of both these latter series have the common character that the peripheral zone of the tubercular nodule is a regular adenoid tissue, being composed of a delicate reticulum which includes small lymphoid corpuscles; this adenoid tissue is in continuity with the tissue of the interalveolar trabeculæ above mentioned. In these stages of the tuberculous process, we find numerous branches of large blood-vessels in the immediate neighbourhood of the nodules, provided with the same perivascular cords of adenoid tissue as have been described in the tuberculous lung of the guineapig.

Finally, it may be mentioned that these nodules also grow in circumference, by the alveolar septa of the neighbouring alveoli gradually becoming thickened, while, at the same time, the epithelium of the corresponding alveoli undergoes the changes before described. The capillary vessels of these parts show the same changes as were mentioned in the case of the lung of the guineapig, *i.e.* they are transformed gradually into nucleated fibres, which may be supposed to be, for a certain time, still permeable by coloured fluids.

If we summarize the results thus described, it is evident that the changes in the acute process of miliary tuberculosis in man are only to a limited extent similar to those which occur in the process of artificial tuberculosis in guineapigs. In the lung of tuberculized guineapigs the first structural changes may be briefly characterised as consisting in the appearance of perivascular lymphangeal nodules, whereas the changes of the interalveolar tissue and the alveolar epithelium form only a secondary process. In miliary tuberculosis of man, on the other hand, we see that the first changes take place in the alveoli and interalveolar septa, and these changes are followed by the appearance of perivascular cords.

It is therefore probable that, in artificial tuberculosis of the lung of the guineapig, the parts first attacked are the small branches of the pulmonary artery or pulmonary vein, whereas in acute miliary tuberculosis of man the capillary blood-vessels of the alveoli seem to be the tissue from which the action of the morbid agent starts.

No. 4.

Anatomical Research towards the Ætiology of Cancer, by Dr. Creighton.

Various meanings of the term "cancer."

The name "cancer" as applied to a kind of tumour contains in it no definition of the object. According to the current explanations of its origin the name is purely fanciful. It is said by some writers to have been applied to certain tumours of common occurrence to signify their gradual and persistent progress. According to others, the name originated in the resemblance of the spreading veins, often seen in the cancerous breast, to the extended claws of the crab. Virchow, who quotes the latter explanation, supports it by the fact that the condition of *pannus*, depending on the unwonted appearance of branching blood vessels in the cornea, was at one time also known as carcinoma. In the latter view the name connotes by a round-about way, a property of the disease that is entirely accidental; in the former view, the name conveys also in a metaphorical form, the sum of qualities implied in the term "malignant;" and it is no doubt on account of this figurative meaning precariously associated with it, that the name of cancer is still retained in the scientific classification of diseases. From its metaphorical nature it is, however, quite unfitted ever to become a general name in medicine connoting a certain definite assemblage of attributes. As a figurative expression it implies with sufficient fullness all that is implied in the term "malignancy," and its proper function may be considered to be that of an additional and colloquial name for all tumours whatsoever that prove to be malignant.

But unfortunately as tumours have come to be more thoroughly investigated, the term cancer has had assigned to it by courtesy a certain definite connotation quite foreign to, and not at all suggested by its etymology. Pathologists chiefly in Germany have retained the figurative name of cancer, side by side with such anatomical terms as enchondroma, myxoma, &c., as the generic name of a greater part of the new growths that have an epithelial type of structure. This arrangement, illogical in itself and tending to the confusion of students, came about naturally enough. At an early date in the study of disease, the word cancer in one form or another was applied to several very distinct diseases, including *pannus* (carcinoma), already mentioned, noma (*cancer aquaticus*), and chancre. These came to be detached from the cancerous group before the time of accurate microscopic investigation, but since the discovery of the different tissues of the body, the process of detachment has been very much extended. The law of Johannes Müller that all tumours correspond in their structure to one or other of the various tissues of the body, formed the basis of a scientific classification of tumours. Müller himself erected the class of enchondromata. Hannover applied the term epithelioma to a class of tumours also known as cancroid, while Virchow defined the new classes of myxomata, gliomata, and most important of all, sarcomata. The latter term had previously existed as it were in rivalry with the term cancer, and was applied with equal uncertainty. Thus J. F. Meckel spoke of a "pankreasartiges Sarcom." Unlike cancer, however, it did connote certain objective characters of new growths, and on this ground it has been retained by Virchow as being capable of a scientific definition. It implied originally a kind of structure resembling exuberant granulations, and inasmuch as

the new growths developing from cells of the connective-tissue series are supposed to pass through a stage of "indifferent granulation," this common point in their history has been laid hold of as the limited generalisation which shall be conveyed in the name.

Thus there have been drafted off under new classes a very large number of the heterogeneous assemblage of tumours at one time known as cancerous. The residue are tumours of an epithelial type of structure, including some that had from the first been considered as pre-eminently cancerous, such as tumours of the female breast, and of the stomach; and for this residue the original unscientific and fanciful name has been retained. The question remains whether the term cancer should not rather be employed as a general synonym for malignant tumours, when such are spoken of solely in respect of their malignancy and without reference to their histology; that is to say, as a convenient additional name implying no more than is implied in the original metaphor. In this country modern usage has practically given this signification to cancer. But if cancer is to be employed in this sense, and not as in foreign writings, also in the histological sense, it remains to find a scientific term which shall be a name for new growths of epithelial origin, as sarcoma is a general name for tumours of a connective-tissue origin.

There is, however, a fundamental want of agreement as to whether new growths of an epithelial type of structure do actually develop from epithelium. Professor Virchow holds that the all-pervading connective tissue is the *matrix* of these as well as of the connective-tissue growths proper, just as the school of pathologists, which it is his merit to have superseded, held that an all-pervading blastema was the *matrix* of every new growth. Till there is more agreement on this point, a scientific name for the tumours of epithelial-like structure, based as it will necessarily be on their histogenesis, must be postponed.

Unsuccessful attempts to produce cancer artificially.

In making a systematic investigation of points in the histogenesis and causation of malignant tumours, it was obvious at the outset that the investigation would be facilitated very much if such tumours could be produced artificially. Not only would the channels of infection, and perhaps the agents of infection, be discovered, but the disease itself, the product of the infection, might be obtained at the various stages of its development, and, to speak generally, under conditions that could be varied to suit the requirements of the research. Attempts were therefore made to propagate cancerous tumours artificially, by means of the injection of the cancerous juices, and by the grafting of portions of tumours among the tissues of an animal. Previous experimenters having failed in the attempt to graft portions of cancerous tumours from the human subject on dogs, occasion was taken to graft from one dog to another, and, in the case of a mammary tumour in the cat, from that animal to another of the same species. The experiments in dogs failed in several cases from the difficulty in retaining the graft in the animal designed for infection. In two cases, however, thin slices of the granulating surface of mammary tumours were applied to previously prepared granulating surfaces of the subcutaneous tissue in other dogs, and successfully retained by stitching the skin over them. In both cases no growth at the point of grafting took place, but a thickening under the cicatrix, corresponding to the size of the graft introduced, could be felt for some weeks after. A dissection was not made of these cases, but there is no doubt that the grafts, as in former experiments where portion of tumours of the human subject were grafted on animals, became surrounded by a fibrous investment as if they had been foreign bodies and incapable of being incorporated with the surrounding tissues. The

injection of the cancer juice under the skin was tried in several cases without effect. Both in these and in the grafting experiments care was taken that no interval should elapse between the removal of the tumour and the commencement of the experiment, so that the tumour elements used for inoculation presumably retained their vitality. These experiments were very limited in number, for the case of the inoculation of tubercle appeared not to be an analogous case, and beyond the supposed analogy of tubercle there was nothing to indicate the conditions under which cancer might be produced.

Microscopic investigation of secondary malignant tumours in the liver.

Recourse was then had to the microscopic examination of new growths with material procured in the ordinary way of *post-mortem* examination. Reversing the order of sequence, secondary tumours, chiefly in the liver, and also in the lung, kidney, and serous membranes were first made the subject of an investigation.* It seemed probable that the minute examination of secondary tumours in the liver, in a series of cases where the primary tumours were of various texture, would throw some light on the common element of malignancy to which they owed their origin. The liver was, as it were, neutral ground, in which the malignancy of the parent tumours, whether they were cancerous (epithelial), sarcomatous, or lymphomatous, manifested itself. The tumour-nodules in the liver were further recommended for investigation by a circumstance of the first importance in an investigation having reference to histo-genesis. Although it generally happens, in cases where secondary tumours are found, that the disease as a whole has fully developed itself, and has been indeed the cause of death, it is not uncommon to find the secondary nodules in one organ or another in all stages of development, from the most initial up to the most advanced. Thus, in one of the cases to be hereafter referred to, the lungs contained secondary tumours so broken down as to be hardly available for minute examination, whereas the liver contained only two or three very small nodules, which were presumably, from their size and isolation, the very earliest manifestation of the disease in that organ.

Enumeration of cases.

The tumour-nodules in the liver occurred as secondary growths in the following cases:—

1. Cancerous tumour (of tubular gland structure) of the ascending colon, in a horse examined *post-mortem* at the Brown Institution. The nodules in the liver were numerous, and varied in size from a billiard ball to a small nut. The peritoneum, chiefly of the diaphragm, and also of the abdominal parietes, was the seat of numerous small nodules, often fused into cords.
2. Spindle-celled sarcoma (melanotic) of the front of the leg, back of the shoulder, and other parts of the subcutaneous tissue, in a female patient under the care of Mr. Croft in St. Thomas's hospital. The liver nodules were numerous, and of various sizes. Some of them were marked with melanosis, and others presented the usual whitish appearance of liver tumours. Large melanotic tumours, very much softened, were found also in the axilla and at the root of the lung. The pleura contained a good many small melanotic nodules.
3. Myxo-sarcoma growing from the posterior aspect of the lower end of the femur in a male patient, aged 24, under the care of Mr.

* The present account is limited to the observations in the liver. It may be stated, however, that strong confirmatory evidence was derived from several cases of secondary growths in the lung.

Le Gros Clark, in St. Thomas's Hospital. The liver nodules were three in number, from ½ to ¼ inch diameter, situated in the upper periphery of the organ. The lungs and pleuræ contained several osseous masses, some of them as large as a walnut.

4. Lymphomatous tumours of large size in the spleen of a dog examined *post-mortem* at the Brown Institution. Attention was drawn to the liver by several small white nodules near its surface the size of a pin-head. The thyroid body on one side was greatly enlarged and otherwise changed.

5. Large spherical white tumours in the liver similar to those found in the spleen in No. 4, also in a dog examined at the Brown Institution. No seat of disease, that could be called primary with reference to the liver tumours, was found.

6. Tumour of the upper jaw, of soft consistence, and containing many giant cells, in a male patient, aged 30, under the care of Mr. Simon, in St. Thomas's Hospital. The secondary disease was very extensively distributed within the abdomen and in the lungs. The liver tumours were numerous, and varied in size from 2 inches diameter to ¼ inch.

7. Cancer of the rectum in a patient who died in Charing Cross Hospital. The liver nodules were many of them in an early stage of development. (The material in this case was preserved by Dr. Bruce.)

8. Cancer of the neck of the womb in a patient under the care of Dr. Barnes, in St. Thomas's Hospital. The liver nodules were few in number, and very small.

9. Cystic disease of the ovary in a patient under the care of Mr. Sydney Jones, in St. Thomas's Hospital. The liver contained one spherical nodule, about ½ inch in diameter, abruptly marked off from the surrounding tissue, but wanting the white appearance of an actual tumour nodule.

10. Whitish masses in the liver of a dog, of uncertain origin. (This case is not introduced as a case of malignant tumour, but for purposes of illustration.)

Analysis of the cases.

In cases No. 4, 9, and 10 the nodules in the liver are to be considered as in the initial stage, and, when taken by themselves, as of doubtful origin and destiny.

In cases No. 1, 2, 6, and 7 the secondary tumours had a remarkable resemblance to the primary, not only in the form and size of the cells, but also the arrangement of the stroma, where such existed (1, 6, and 7).

In case No. 3 the primary tumour had at certain points a well-marked myxomatous structure, while at other points the arrangement of cells and fibres was more nondescript. The nodules in the liver, which were rudimentary, resembled more the nondescript portions of the primary tumour than the myxomatous portions of it.

In case No. 8 the primary new growth at the neck of the uterus was not obtained for examination.

In case No. 5 the liver tumours could not be referred to nor compared with any primary growth (source of infection).

It will thus appear that in five cases there is complete evidence of the identity of the secondary tumours with the primary. The nodules in the liver were composed of large spindle cells, of giant cells, of tubular

gland structure, &c., resembling the parent tumours respectively, and this resemblance extended even to very minute particulars.

Current opinions on the mode of origin of secondary tumours.

The current explanations of the origin of secondary tumours in the liver may be classed under two heads:—1st, those which ascribe the new growth to the multiplication of tumour cells that have wandered to the liver from the primary tumour, and have become centres of cell-proliferation; 2nd, those which ascribe the new growth to a transformation of certain pre-existing elements of the part. The evidence that will be adduced below is entirely in favour of the latter explanation, and will suffice to show what particular elements are transformed, and what is the particular manner of their transformation. The most important statements as regards general pathological doctrines that have been made hitherto on this point are those of Professor Virchow, and it will be necessary to quote them briefly.

The reference to new growths in the liver is preceded by the following statement of one of the cardinal doctrines of the Cellular Pathology: —"Bearing in mind that the lymphatic tracts, in so far as they are "concerned, have a close relation to the connective tissue, we should "still not be in error if, *instead of plastic lymph—the blastema of "earlier writers, the exudation of later—we were, with a few reserva-"tions, to take the connective tissue, with its equivalents and adjuncts, "as the chief matrix-tissue of the body*, and to trace therefrom the "development of the greater part of new formations."

The application of this doctrine to the liver, is summed up in the passage that immediately follows the sentence just quoted:—"If we "take the case of a particular internal organ such as the brain or the "liver, it were difficult to conceive of the formation of a new growth "without the intervention of some special formative material, so long "as one recognised nothing in the brain besides nerve substance, and "in the liver nothing but liver cells and vessels; for one may be easily "convinced that, as a rule, the new growths in the liver do not proceed "from the liver cells or the vessels. . . . But I had first to make "out that there were connective-tissue cells in the liver and interstitial "neuroglia cells in the brain, which are the equivalents of the ordinary "connective-tissue corpuscles. In fact it appears to us, as Reichert "was the first to suggest, that the groundwork of the body is made up "of a more or less continuous mass of connective-tissue elements, in "which, at certain points, other things, such as epithelium, muscles, "vessels, and nerves, are set. It is in this more or less connected "framework that the majority of new growths, according to my in-"vestigations, take origin, and that, too, according to laws the same as "regulate the embryonic development."*

The summary of facts to be given below is put forward as strong evidence that the liver cells, the parenchymatous or predominant cells, and not the cells of the connective tissue of the organ are the elements that undergo transformation. And this evidence will serve among other purposes as a test of the particular doctrine of the cellular pathology that is here quoted.

The process is a transformation of liver cells by vacuolation.

The transformation that the liver cells undergo consists in a vacuolation of their protoplasm, with other associated changes. A description of the usual forms of vacuolated cells met with in the cases above enumerated will first be given. Secondly, it will be attempted to show that

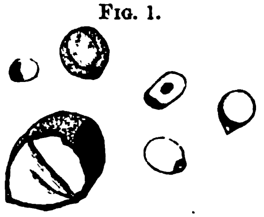
* Cellular Pathologie, p. 485.

the vacuolation of liver cells stands in a causal relation to the formation of tumour nodules. Thirdly, the nature of the vacuolation process and its significance as regards histogenesis will be discussed. Fourthly, the affinities of the vacuolation process, as observed in the formation of secondary tumours, to certain forms of cell change in the normal life of the organism will be pointed out.

Various degrees of vacuolation.

A typical example of a vacuolated liver cell has the appearance of a signet ring. The substance of the cell is excavated to form a vacuole or vesicle, at one side, or on one pole of which is accumulated a mass of protoplasm either of crescentic shape with its two extremities merging gradually in the walls of the vacuole, or as a circumscribed oblong or round lump. It is a question, chiefly of terms, whether the peripheral mass is the nucleus or the substance of the nucleus in an excentric position, but it is an invariable property of this mass, whatever its form, that it is capable of deep staining (by logwood, for example) and that it contrasts in this respect with the rest of the cell. The signet ring form of vacuolated cell here described has been called typical, but a modification of it, in which there is the addition of a round cell, also capable of deep staining, lying free in the vacuole, may be described as a more perfect type. (In describing these forms as typical, it is intended only to make them available as standards of comparison.) In some cases the deeply-coloured peripheral mass is very much larger than in others, and the vacuole proportionately smaller. In other cases, again, the coloured protoplasm is not massed at one point of the circumference, but is, as it were, distributed equally round the whole of it, forming a substantial cell wall. This is chiefly seen in cases 4 and 10, and these cases are so peculiar in this respect that they will be reserved for separate consideration. In still another form or degree of vacuolation, nothing is seen of the original cell but a faint ring, quite uncoloured by the staining fluid, and containing within it a round cell which, on the other hand, is deeply coloured.

FIG. 1.



Various forms of vacuolated cells occurring among the tumour cells. The large cell at the left lower corner is from case 6 (giant-celled). (Hartnack, Oc. 3, Obj. 7.)

The different kinds of vacuolation here described are evidently modifications of one and the same process.

Contents of the vacuoles.

As regards the contents of the vacuoles the observations are defective. The specimens used for the investigation were preserved for a considerable time in spirit, and the sections of them were mounted in a solution of Canada balsam. After this preparation the vacuoles had generally the appearance of being empty, as if their contents had been dissolved out, and it is highly probable that they were originally occupied by fat. In a number of cells in cases 3, 6, and 7, the vacuoles were filled with a fluid substance which became stained by the logwood in the same way as mucin (for instance in the thyroid body), and in other cases they presented the appearance of being filled with a thin granular protoplasm. The question of contents will be considered again later. It is sufficient for the present to direct attention to the deeply-coloured masses of protoplasm associated with the vacuolated cell in one form or another, for these are factors that can be reckoned with by themselves and independently of the accompanying fluid products.

Vacuolation casually related to production of tumour-nodules.

The above description of vacuolation is taken from liver cells still distinguishable as such, grouped either in acini or cylinders, or lying

more or less isolated. It has next to be shown what reason there is for supposing a connexion to exist between the process of vacuolation and the formation of the tumour cells. An *à fortiori* proof of this will be given in describing in detail the manner in which particular vacuolated cells give rise to tumour cells, but there is a certain amount of general evidence of the relation between vacuolation and the growth of secondary tumours, which may be stated in the first place.

Primâ facie evidence.

The most instructive case for this purpose is the fourth in the above list. The greatly enlarged spleen contained several large white tumours of a well-marked lymphomatous structure. They were spherical in shape, some of them projected about an inch above the surface, and they were all definitely circumscribed from the surrounding splenic tissue. The liver contained a number of small white pin-head nodules, several of them visible on the surface. On section through one of these it was found that the liver tissue, for a radius of about $\frac{1}{4}$ inch round the small white nodule, and to a depth of $\frac{3}{4}$ inch, had a colour different from the rest of the liver. This area of altered liver tissue corresponded exactly to the usual cup-shaped outline of a tumour nodule in the periphery of the liver, and on microscopic examination it was found that it was an area of general vacuolation of the liver cells, and that it was definitely bounded from the adjacent liver tissue, which was normal. It is impossible to regard this appearance otherwise than as the initial stage of a new growth, such as was fully developed in the spleen. Again, in case 1, there appeared round a white nodule a zone of tissue of less marked whiteness. This zone was found to be liver tissue in a state of vacuolation, having already acquired a certain resemblance to the more developed tumour tissue that lay within it. In case 2 (spindle-celled sarcoma) nodules were found divided into smaller areas by bands of fibrillar tissue. Among the areas composed of spindle cells there occurred one or two also marked off by the fibrillar septa, which were composed of cells still distinguishable as vacuolated liver cells.

Such instances as these serve to establish a *primâ facie* connexion between the vacuolation process and the growth of the tumour. The exact nature of this relationship will now be described. It may be stated at the outset that it is not to be seen with equal clearness in all the cases enumerated. Case 8, for example, would not probably of itself have suggested such an origin of the tumour cells, but taken along with the others it brings a certain amount of confirmation. The most instructive sections were obtained from cases 1, 2, 3, 6, and 7.

Particular evidence.

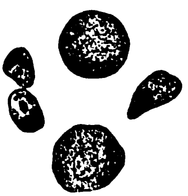
It may be said, in general, that the deeply stained mass of protoplasm remaining from the vacuolation of the cell, whether it occupies the periphery of the vacuole or exists as a free cell within it, is the first stage of the tumour cell, which henceforth enjoys an independent existence, and develops, so to speak, on a new departure. The varieties of its origin are naturally as numerous as the modifications of the vacuolation process. Where the latter is so extensive that only a small round cell survives within the faint outline or skeleton of the original liver cell, the tumour element commences at the lowest stage of "indifference," or the granulation stage, and may either go on to attain the characters of a cell in the primary growth, or, as there is reason to suppose, it may fall short of this. Coming next to the signet-ring type of vacuolated cell, two modifications in its progress towards a tumour cell are found. In the first of these the peripheral mass becomes detached from the more or less slender ring of the vacuole, which in its turn atrophies or disappears in one way or another. It may be well to notify

here that in describing the steps of this process, as in the description of all processes of cell-change from *post-mortem* appearances, one is obliged to speak as if the successive steps were observed in the same element. What is observed is, of course, a number of cells of the same kind in different stages of the same process. The subsequent progress of these disengaged masses, as well as of the small round cells described as the first variety, may be made out with tolerable certainty. It is of course evident from their property of deep staining that they are destined to a development of some kind. The particular evidence that they become tumour cells consists in the fact that they are found in all transition stages, and in such proximity as to make the relationship not at all doubtful. But it is in the other varieties of the vacuolation process that the evidence of identity is most direct. In a very large number of the cells, especially in cases 3 and 6, the outline of the vacuole persists. These are cases of the signet-ring type of vacuolation in which the wall of the vacuole is a more or less substantial prolongation of the crescentic peripheral mass, and capable of a faint degree of staining. The vacuole, as has been said, does not break up, as in the former case, but remains attached to the chief element in the new growth, the peripheral mass, and can be identified in the mature tumour cell. What was the vacuole becomes filled with a pale granular protoplasm, the highly coloured peripheral mass remaining in the same relation to it as it did to the vacuole while the entire cell could still be called a liver cell. An appearance observed several times (in cases 3, 6, and 7), is probably to be considered as the stage intermediate between the first vacuolation of the liver cell, with its probably oily contents, and the stage in which the vacuole was filled with a pale protoplasm. In these cases, which have already been mentioned, the vacuoles were filled with a fluid which coloured in the same way as mucin, and was therefore to be considered albuminous.

Fig. 2.

From the liver in case 3. Vacuolated liver cylinders, occurring side by side with the mature tumour cells, and showing production of small round cells. (Oc. 3, Obj. 7.)

Fig. 3.



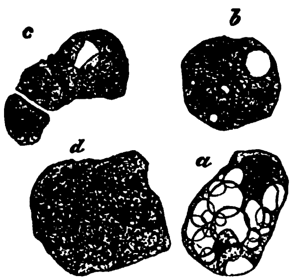
Cells from various liver tumours, giving the appearance of vacuoles that have been filled with granular protoplasm. (Oc. 3, Obj. 7.)

There was no doubt of the identity of these cells with liver cells, on the one hand, for they occurred in unmistakeable liver cylinders, and there was equally little doubt as to their relationship to tumour cells on the other hand, for they occurred (in very young nodules) in the midst of tumour cells in all stages of development. The occurrence of an albuminous fluid in the vacuoles suggests that if, as is probably the case, the original contents in the case of liver cells, are of an oily character, a substitution takes place of an albuminous fluid, which in its turn assumes a more or less solid protoplasmic character. A similar substitution has been observed in the subcutaneous fat and in the medulla of bone. In many cases the protoplasm which the peripheral mass attracts to it or secretes, is disposed not only within the outline of the old vacuole, but also as a fringe round the entire cell. But in a very large number of cells, in cases 3 and 6 (both sarcomatous), the appearance of vacuolation, depending as it does on the deeper colouring of the outline of the cell and of the peripheral mass, remained after the

contents of the vacuole had ceased to be fluid, and afforded, at the first glance, a remarkable proof of identity.

The giant cells that occurred in great numbers in case 6, and to a lesser extent in case 3, are interesting in themselves, and will be spoken of again when the nature of the vacuolation process is discussed. For the present purpose they serve to show clearly the relation between the liver cells and the tumour cells. The mature giant cells of the tumour contained nuclei generally varying in number, in proportion to the size of the cell, from two or three up to 20 or more. The nuclei were not less in size than a white blood corpuscle, and a cell with many nuclei formed, therefore, a very large object. In several of the cells the nuclei were arranged round the circumference of the cell like a necklace, leaving the centre free. Cells of this size were seen among the liver cells, sometimes grouped together and facetted like a cluster of liver cells, having the characteristic brownish protoplasm of the liver, and differing in no other respect from the cells of the organ, except in their size and the occasional absence of a nucleus. The next stage was represented by cells evidently corresponding in size and general appearance to the former, in which the entire substance of the cell was occupied by a number of clear round or oval vacuoles. In one cell a coloured nucleus, presumably the original nucleus of the liver cell, was observed at one end, having its border scooped out at various points corresponding to the segments of vacuoles clustered round it and encroaching upon it. The nucleus had thus a stellate appearance, with its rays or processes separating for some little distance the vacuoles grouped round it. The last stage is the mature stage of the giant cell, where the vacuoles are no longer visible, but instead of them coloured nuclei, apparently to the same number and in the same positions. In others of the giant cells, belonging probably to the intermediate stage, vacuoles were seen containing small round cells in their centre, with a greyish granular protoplasm filling up the rest of the space. In still another form each vacuole had a crescentic coloured mass of protoplasm on one side of it.

FIG. 4.



Cells from case 6 (giant-celled tumour) showing various stages of development, *b* representing a stage intermediate between *a* and *d*. (Oc. 3, Obj. 7.)

All the degrees of vacuolation may be found in the same case.

In the cases from which the preceding descriptions are drawn, the various modifications of the vacuolar process were generally present together. Thus, among the giant cells there occurred cells of the ordinary signet-ring type, while in case 3 there occurred along with cells that retained the outline of the vacuole, others in which the peripheral mass alone developed. The variety in which only a small round cell survived the vacuolation occurred in nearly all the cases. It frequently occurred that in the midst of an area of more or less developed tumour cells with bright colouring there were found greyish patches with a number of small coloured cells strewn over them. On closer examination the ground substance or soil of these patches was found to consist of the pale, ring-like skeletons of vacuolated liver cells, within many of which lay the small, coloured, round cells corresponding to those spoken of before as "indifferent," or granulation cells. It is possible to infer from these appearances either that all the rest of the tumour had passed through the same stage, and that those particular parts were backward

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in their development, or that in some parts of the liver tissue undergoing transformation the cells had undergone a greater degree of vacuolation than in the others, and had been first reduced to the "indifferent" or granulation stage before taking on the characters of tumour cells. From the independent proofs given above the latter explanation is the more probable. An impression also conveyed by these same patches of vacuolated cells is that the number of round cells resulting from the process is smaller than the number of liver cells involved, and it is at least probable that the products of vacuolation not unfrequently abort.

Other issues of the vacuolation process.

Again, though it is quite certain that those indifferent round cells do very generally develop into mature tumour cells, there is good reason to suppose that in some cases they terminate in a fibrillar or adenoid kind of tissue, which may be called cicatricial, in contrast to the tissue of the new growth. The evidence in favour of this notion is derived from case 1, and more especially from case 2, a spindle-celled sarcoma. In the latter certain bands of fibrillar tissue are seen to merge with areas of small round cells, the relation of which to the liver cells on the one hand and to the tumour cells on the other rests on independent evidence. Another observation in connexion with these fibrillar bands of tissue is that they sometimes contained, as if imprisoned in their midst, small clusters of liver cells in a state of vacuolation. We are thus brought face to face with the notion, that not only the vacuolation of liver cells can issue in the formation of a fibrillar or cicatricial tissue, but that the same vacuolation process which in one group of liver cells may give rise to tumour elements may, in an adjoining group of liver cells, give rise to the comparatively safe product spoken of as fibrillar or cicatricial.* It is to be observed, however, that this, in so far as it is proved to occur at all, can only occur where the vacuolation has been of the extreme kind, and where the surviving product is a small round granulation cell.

The structure of the lymphomatous tumours shows an approximation to the above-mentioned fibrillar tissue, while they still retain their character of new growths in the strict sense of the term. In case 4, described already has showing a *primâ facie* case for the connexion of vacuolation and the growth of secondary tumour, the vacuolation of a tract of liver cells was of such a kind that the resulting appearance was that of a coarse network, in the meshes of which lay round cells, more numerous at some parts than at others. A later stage of the development was not seen in this case, and in the other case of lymphomatous tumours (No. 5) the same early stage was not observed. The evidence, therefore, taken as it stands, is not conclusive, but there is nothing hazardous in supposing that the coarse network, with the small cells in its meshes, as seen in No. 4, would have subsequently assumed the character of true lymphomatous or adenoid tissue. In this case the fibrous network was formed by the substantial coloured walls of the contiguous liver cells. That the network was formed actually by

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* The observations of Holm and of Hüttenbrenner on the process of repair after wounds of the liver are of interest in this connexion. The cicatricial tissue was found to be derived from the liver cells, and the first stage of the reparative process was found to be a filling of the liver cells with fat. It has also been contended that the connective tissue in cirrhoris of the liver is derived from the liver cell, and the associated presence of fat in the liver cells has been remarked. Among others, Dr. Wickham Legg, (St. Bartholomew's Hospital Reports, 1872,) argues for the development of the connective tissue in cirrhosis from the liver cells, but the so-called "fatty infiltration" does not enter into his own description of the process.

vacuolated liver cells in close apposition, and not, for example, by the *tela conjunctiva* of the organ, was quite clearly shown by the fact that there occurred in the same preparations, and contiguous with the net-work, liver cells in which the vacuoles were smaller and the peripheral masses larger, and all gradations of the process.

The process of transformation in the liver cells has hitherto been spoken of from a purely morphological point of view as vacuolation, and the evidence has necessarily taken the direction of identifying particular stages of the vacuolation process with particular appearances in the tumour cells. It is now proposed to examine the nature of the vacuolation process, and its significance as regards histogenesis. This is the third of the points set down for discussion, and it may be disposed of briefly.

Vacuolation, as here described, is the process of endogenous cell formation.

Vacuolation, as described in the preceding account, is the process that is known as endogenous cell formation. The signet-ring type of cell, or that form, with the addition of a free round cell in the vacuole, may be considered as a diagramatic representation of endogenous cell formation. Professor Virchow has described exactly the same forms of cells under the name of "physaliphoren," in order to distinguish their vacuoles from such transient vacuolar appearances as occur, for example, in a pus corpuscle, or a white blood corpuscle, during its amœboid movements. These are described as a variety of the endogenous mode of cell formation. It is scarcely necessary to illustrate this point at greater length.

The only other probable view is that vacuolation is a form of necrobiosis of the cells in which it occurs, and as regards the vacuolated liver cells, which presumably contained at one time fat in their vacuoles, such an opinion would no doubt occur to those who think, without discrimination, that the mere presence of a fat globule in a liver cell is an evidence of its decay. It may be an evidence of its decay as a liver cell, but it is no evidence that it has lost any of that plastic force or power of transformation which is inherent in it as an element of the body.

It seems certain, however, from appearances observed in the cases forming the subject of this research, that a certain proportion of vacuolated liver cells do vanish entirely, leaving no product, which fact has been adverted to above, when it was said that the products of vacuolation in some cases aborted. But in the great majority of vacuolated cells, the one conspicuous and important thing is the deeply-stained and therefore vigorous mass of protoplasm that survives the vacuolation in one form or another. Even in those vacuolated cells in which the form and substance of the original cell have all but disappeared, the small round cells appear as bright coloured masses within the still obvious outline of the vacuole. This frequent and characteristic appearance suggests nothing so much as that the highly coloured and active young cell had sprung, as it were, from the ashes of the old one.* So long as such products result from the vacuolation, that process cannot be called one of necrobiosis.

Before leaving the subject of vacuolation regarded as the process of endogenous cell formation, the giant cells that occurred in cases 3

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* The appearances figured and described by AxelKey and Wallis (Virchow's Archiv., Vol. 55,) as occurring in the corneal corpuscules after inflammation, set up by pencilling with lunar caustic, are very similar to those here referred to, although a different interpretation is put upon them.

and 6 may be again referred to. Although the phenomenon of giant cells is sometimes attributed to a tardy or sluggish division of the protoplasm in the ordinary hyperplastic mode of cell growth, viz., by division, yet in the present case it was obvious both from the circumstances in which they were found, and from the presence of one or more vacuoles in them, that they were a product of endogenous cell formation.

The endogenous mode of cell growth is contrasted with the usual mode of cell-formation by division, and is frequently exemplified in the vegetable kingdom. If cell-formation by division is the hyperplastic process, wherein the new cell is merely a repetition of the old, the endogenous mode of cell-formation is the metaplastic process, in which the product departs from the type of the parent cell and acquires differential characters of its own.*

In the above cases, the results of the vacuolation process are found to correspond with the results to be looked for where the endogenous mode of cell-growth is resorted to. In one case the resulting cells became large spindle cells, in another case they became giant cells, in another columnar epithelium, the mature product in each case being different in type from the cell that produced it. The law of the continuity of the tissues, which would have been observed in the purely hyperplastic mode of cell formation, is, so to speak, abrogated by introducing the factor of endogenous cell growth; so that liver cells become the parents of sarcomatous cells or epithelial cells indifferently, and the epithelial cells, though belonging to the same group as the liver cells, are no more the hyperplastic products of the latter than are the spindle cells.

Summary of the argument.

To summarise the preceding statements, it may be said that secondary tumours in the liver originate in certain changes that go on in the liver cells simultaneously at various points, and that the efficient cause of their formation is the substitution of the endogenous or heteroplastic mode of cell-growth, whereby an alien product takes origin, for the normal plastic activity of the liver cells, whereby the organ is either maintained at a certain point or at the most undergoes a simple hyperplasia. As the ground in which tumours of very various characters may develop, the parenchyma of the liver may be regarded as a sort of indifferent matrix whose products owe their form, not to any influence that can be imparted to the liver cells as such, but to an extraneous influence. The mechanism, again, in nature by which this result is brought about, and by which this extraneous influence operates is the process of endogenous cell-formation.

The extraneous influence is, however, an assumption, and it now falls to be considered what reason there is for assuming the existence of such an influence.

The relation of primary tumours to secondary.

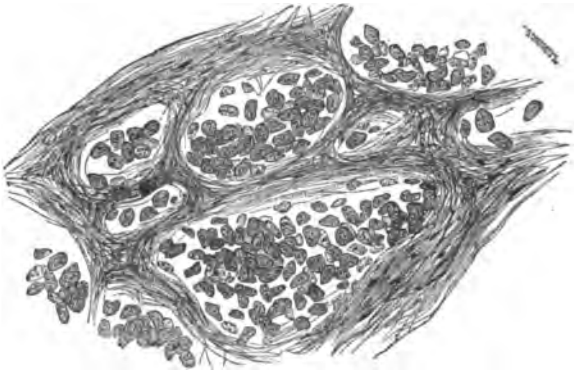
It has been already stated that the tumours in the liver had generally a remarkable resemblance, even in minute particulars,† to the tumours in other parts of the body, which have hitherto been spoken of as primary. These primary tumours differ from the secondary in the important respect that their elements resemble or at least are histogenetically the equivalents of the cells proper to the situation in which they grow. Thus, the sarcomatous tumours (2, 3, and 6,) originated in connective tissue structures, while the epithelial tumours (1, 7, and 8,)

* Virchow, Cellular Pathologie, p. 491.

† The mode of development of the characteristic stroma in the various tumours has been omitted for the present.

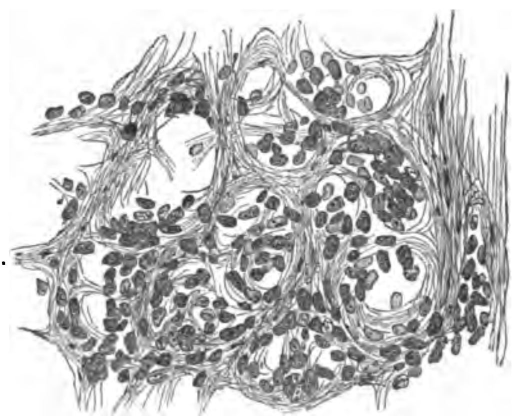
originated in mucous membrane. There is here, then, a fundamental difference between the primary and the secondary tumour, and there is no doubt also that the primary is the first in point of time. Admitting,

Fig. 5.



From the primary growth in the rectum, in case 7. (Oc. 3, Obj. 7.)

Fig. 6.



From a secondary nodule in the liver, in case 7 (cancer of the rectum). Same magnifying power.

then, that the tumours in the two situations are not two coexistent growths having their origin in a common cause, and that the one is "secondary to" or dependent on the other, the relation of parent and offspring must be admitted at the same time. The resemblance between the primary and secondary tumours is comparable to no other relation in nature than that of parent and offspring. The extraneous influence, therefore, which is necessary to explain the origin of the secondary tumours, is to be compared to a spermatic influence produced in some unknown manner by the parent tumour. But there is also a histological reason in support of this analogy.

Vacuolation of cells compared to the first changes in the ovum after fertilisation.

It is not altogether fanciful to trace a similarity between the changes that the ovum undergoes after fertilization and the changes in a cell, such as a liver cell, undergoing vacuolation; and such a comparison would probably appear less fanciful if the first changes produced by impregnation of the ovum were better understood. It is generally agreed, among much that is doubtful, that in the ovum, after fertiliza-

tion, the nucleus disappears,—whether a complete disappearance or a change to a position where it cannot be traced, is uncertain,—and that in the place of it there appears a vacuole or cavity (nucleus cavity). These changes, whatever they may signify, are the direct and earliest effects of fertilization. Now the process of vacuolation may be described in similar terms: the nucleus, as such, disappears, and a cavity, which may, however, be very much larger than the nucleus, appears in its place. There is to be added also, as regards vacuolation, that what was the nucleus, or at least the substance of it, reappears either at one pole of the cell or as a round mass lying free in the cavity. Although the parallel cannot be continued far, there is similarity enough in the manner of transformation in both cases to make it probable that the cause is similar. Thus we have additional evidence that the extraneous influence in the production of secondary tumours is comparable to a spermatic influence.

Occurrence of vacuolation in other pathological conditions;

The process of vacuolation that has been described above as concerned in the formation of tumour cells, occurs in other pathological conditions, and there are good reasons for considering an important class of cell changes in the normal organism to be a process of the same nature. Setting aside the occurrence of the characteristic vacuolated cell among the products of inflammation of the synovial membranes of joints, and of other serous membranes, we shall limit our attention to the occurrence of the vacuolation process in the epithelium of mucous membranes. Vacuolated cells were described by Remak as occurring among the products of catarrh of the respiratory mucous membrane, and this observation has been made familiar by subsequent descriptions. In this case there is no doubt of the nature of the phenomenon, but other instances that are about to be adduced as exemplifying the same process are not equally admitted. Many of the cells found in colostrum have a greater or less resemblance to the forms of vacuolated cells described above. Thus Langer describes cells containing a vesicle filled by a fat globule and having a crescentic mass of protoplasm disposed on one side.* The epithelial cells of the testis employed in the formation of spermatozoa frequently exhibit the characteristic appearances of vacuolation, and La Valette describes as occurring in the seminal fluid shapeless masses of protoplasm, which he identifies with the corresponding masses found in colostrum. They are said by him to be probably "unverbrauchte Protoplasmareste," as it were, waste products of the epithelium produced along with the spermatozoa.† Again, the salivary and mucous corpuscles are cellular bodies formed from the epithelium along with the proper secretion, and whether they occur only in a catarrhal state of the gland or in the normal condition is unessential to the present argument. The peculiar cup-shaped appearance of many goblet cells, depending on a crescentic mass of protoplasm at their attached border, and prolongation of the same on each side of the cell, has a real resemblance to a vacuolated cell. The crescentic mass and the lateral prolongations of it are distinguished by their property of deep staining in exactly the same way as the peripheral mass in a vacuolated cell.

and under normal conditions.

It is contended that in the above instances there is a resemblance, as regards the form of the cells, to the product of vacuolation previously described, and the following considerations are brought forward in proof of an identity in the mode of their production.

In the production of secretion from mucous surfaces (that is to say,

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* Stricker's Handbook, p. 632.
† Stricker's Handbook, Art. The Testicle.

in all cases except the parenchymatous organs, the liver and kidney), the secretion is formed if not entirely at least in a great measure at the expense of the individual epithelial cells. This is most obvious in the case of the mammary and sebaceous glands, but although it has not been clearly proved for all other cases, there is no doubt that it is the general law for the epithelium of surfaces. This law is expressed in the following terms in MM. Cornil and Ranvier's Manual of Pathological Histology:*

"This evolution is the leading physiological fact of all epithelium: all "their elements are transitory, being born, coming to maturity, and "dying within a variable space of time. . . . It is a well-proved "fact that, in glands, the epithelial cells are shed to give exit to the "excreted substances, and that their own contents are an essential part "of the secretion. . . . Glandular epithelium, of which the cells "may be of the pavement variety, or cylindrical, pyramidal, &c., is the "subject of a constant evolution. Thus it is that in the glands of the "stomach one sees the cells that are at first cylindrical becoming "spherical from distending themselves with juice, falling into the "lumen of the gland, aud getting destroyed in the act of giving up "their contents. So the cells of colostrum are no other than the cells "of the mammary acini, and although in the milk they are no longer to "be found, it is because the cells are destroyed in setting free the fat "which they contain."

The vacuolation process in secreting epithelium.

Now the occasional occurrence of protoplasmic masses in association with the fluid products of secreting cells has an important significance in respect of the essential nature of the secretory process. We are, in fact, entitled to argue that there is potentially present in every secreting cell, both a fluid or vesicular and a cellular product, and that there is a co-relation between those two. Where the substance of the epithelial cell is most completely devoted to the formation of the secretion, the solid product is reduced to a minimum, and in those cases where the solid product of the secretory cell, so to speak, asserts itself, the secretion loses accordingly. The best example of this is the colostrum or half-formed secretion of the mammary gland, where the mammary epithelium, instead of being entirely transformed into milk drops, undergoes only a partial transformation, leaving a certain amount of the protoplasm as an accessory product. The catarrhal cells of the bronchi are probably to be explained on the same principle. Salivary and mucous corpuscles, if indeed they also are not due to a catarrhal condition of the mucous surface, are to be regarded as instances where the cellular elements in the secretion have no pathological import. The crescentic masses that form the base of goblet cells, and the protoplasmic bodies found in the seminal secretion are of sufficiently common occurrence to be regarded as normal. The spermatozoa themselves, as well as the ova, may be adduced as instances of solid products formed in the vacuoles of epithelial cells, and if this interpretation of the seminal and ovarian secretions be correct, we are here furnished with an instance where, in the secretion of epithelial cells, the solid product becomes the essential, and the fluid the accessory.

Secretion a process of endogenous cell formation.

The conclusion, then, that we arrive at from the above considerations is, that the process of secretion in the epithelial cells of mucous surfaces is essentially a process of endogenous cell-formation.

The account usually given of the production of secretion in the

* Manuel d'Histologie Pathologique, p. 29.

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epithelial cells is merely pictorial; a passage already quoted will serve as an example:

"C'est ainsi que dans les glandes de l'estomac on voit des cellules "primitivement cylindriques devenir sphériques en se gorgeant de "sucs, tomber dans la lumière de la glande et se détruire en laissant "échapper leur contenu."

As so expressed, the life of the secreting cell is nothing else than a chapter of accidents, a succession of events apparently arbitrary in their occurrence. If, however, the law of endogenous cell-formation be applied to this particular form of cellular activity, the various changes in the cell find a rational explanation. The most valid objection to such an explanation will be found to be directed against the terms employed. It is true that in most of the cases that are here referred to the so-called process of endogenous cell-formation, no cells are formed; but that is a paradox which depends on the name having been adapted to only a part of a more widely-spread phenomenon. It may be instructive again to contrast the endogenous mode of cell formation with the mode by division. What distinguishes the former, is the collateral production of a vesicle or vacuole containing a fluid, the result of a transformation of the cell protoplasm. In the latter form of cellular activity, the cell divides into several pieces, each of which becomes exactly like the original cell. One might say that in the endogenous mode there is a provision for a fluid product, and it is according to many analogies in nature of the adaptation of a general plan to particular ends, that such provision may be magnified into the essential feature of the process.

In searching for a confirmation of the above hypothesis as to the essential nature of the process in secreting epethelium, the writer has found that a similar view was entertained by a zoologist, Friedrich Will, who is quoted by Professor Virchow in 1851. In making an investigation of the seminal secretion throughout the animal kingdom, Will arrived at the conclusion (as stated by Virchow) that "all secretions proper are the "result of a process of cell formation, and, indeed, of endogenous cell "formation (*durch Zellenbildung, und zwar durch endogene Zellenbil-* "*dung vermittelt*)." Virchow adds, "It is to be hoped that the propo- "sition, thus broadly stated, is to be understood as applying only to "invertebrate animals; but it seems, at least, to indicate the wide "distribution of a phenomenon that has, perhaps, a greater significance "in physiology, and which may lead us, in course of time, to regard "the process of secretion from a higher and more general point of "view."* The theory of Will has not passed into the text-books of physiology, and appears, indeed, to have been lost sight of.

Theory of the malignancy of prmary epithelial tumours.

The hypothesis that the secretory function of mucous membranes is performed by means of a process in the epithelial cells identical with the process that is known, under other circumstances, as endogenous cell-formation, has a very great significance as regards the malignant tumours of epithelial parts. What this significance is may be illustrated in the case of the mammary gland.

Illustrated in the case of the breast.

The colostrum corpuscles that are found in the milk at the commencement of the secretion, and which are observed more perfectly in the acini of glands that have lately ceased to secrete, may be taken as a starting point. They are the epithelial cells that have been shed in a half-transformed state. Their activity is still the functional activity, as contra-distinguished from the plastic; but, owing, no doubt, to an immature or subsiding functional stimulus, their transformation into the fluid of the secretion is incomplete. The fluid contained in their

* Archiv. III., 224.

vacuoles is all that can be called secretion in the proper sense of the term, and from the same point of view the associated mass of protoplasm has a purely negative importance, and is to be viewed as so much waste. But if the epithelial cell is regarded, not as performing a function, but as obeying the law of endogenous cell-formation, it is obvious that the fluid in the vacuole and the solid mass on one side of it are co-ordinate products, each of which is more or less important according to its degree of predominance over the other. Under this correlation, the vacuolation may be extreme and the cellular part insignificant, or *vice versâ*, according to circumstances; and among colostrum cells many gradations are in fact observed. If we consider the complete transformation of the epithelial cell into a fluid substance, as in the normal secretion of milk, to be the case where the vacuolation reaches its extreme limit, we may also conceive of the other extreme in which the solid or cellular element preponderates; and the latter, though in the particular circumstances not a useful product, may be spoken of as also a product of the secretory process. Now, when one calls to mind the special characteristic of cells produced endogenously, the bearing of these points on the question of malignancy will become apparent. It is the characteristic of the products of endogenous cell-formation that they assume a type different from that of their parent cell. As it has been already expressed, the mode of cell-formation by division is the plastic or hyperplastic process, while the endogenous mode is metaplastic. Metaplastic, again, is in pathological language equivalent to heteroplastic. In this manner, then, in the exercise of the glandular function, and by virtue of the law according to which the function is performed, there would be produced, on occasion, from the epithelium of the gland, elements that were not themselves true epithelium, and that were in fact heteroplastic.

Now, continuing the illustration of the mammary gland, there is abundant reason to suppose that in cancer of the breast the epithelium is the point of departure for the new growth. This view is held by many pathologists, notably by Professor Waldeyer, who describes cancerous tumours of the breast (and of other epithelial situations) as a growth of atypical epithelium. But it is precisely the atypical element in the new growth that remains unexplained. There is nothing in the explanation of the histogenesis of the growth given by Professor Waldeyer to show wherein it differs from a mere hyperplasia. Other pathologists, again, such as Professor Virchow, have been led, in the absence of such an explanation, to assign the origin of the epithelial-like cells of the tumour to an "epithelial infection"* of the connective tissue, rejecting, as it were, the strong evidence of epithelial origin for the sake of being able to account for the heteroplasia of the growth. Thus, Virchow, after stating the epithelial theory, and the explanation of the apparent exceptions to it, adds significantly, " Ich meinerseits bin durch diese Ausführ ungen nicht überzeugt; ich halte an der primären Heteroplasie aller Krebse fest."† Now, if it can be shown that the cellular product of secreting epithelium is no longer epithelium, but a heteroplastic product, and that by virtue of the law of endogenous cell-formation, according to which the function is performed, such an objection as is here stated is no longer tenable.

The mammary gland has been taken as an illustration, and it is obvious that the sebaceous glands, and the *rete mucosum* in general,

* The expression is used by Klebs. The theory has been most explicitly stated by Virchow and W. Müller.

† Cell. Path. 4th Edition, p. 469-70.

together with the epithelium of the digestive and genito-urinary tracts, are subject to the same process of reasoning. The attempt would therefore be made to associate the origin of primary tumours of those parts with irregularity in the performance of the function of the part, and to explain the malignancy of tumours so arising.

With this view an investigation was made of a series of mammary tumours. They were 21 in number, 8 of them from the human subject, 11 from the dog, and 2 from the cat. It became apparent, however, in the course of the investigation, that there was another factor, special to the mammary gland, which played a part in the formation of new growths, viz., the periodical evolution and involution of the gland. The information hitherto acquired as to those remarkable changes occurring normally in the mamma, proved unfortunately to be very scanty, and it became necessary to make an original investigation of the subject. This collateral inquiry is not yet (March 1874) far advanced, and a report on the cases of mammary tumours is therefore postponed.

No. 5.

RESEARCHES on the CHEMICAL CONSTITUTION of the BRAIN.

By J. L. W. THUDICHUM, M.D.

APP. No. 5.

On the Chemical Constitution of the Brain, by Dr. Thudichum.

CONTENTS.

I.—METHOD PURSUED FOR THE ISOLATION OF IMMEDIATE PRINCIPLES.

CONTENTS.

Anyone who would proceed to an extensive chemical investigation of the brain finds it impossible under ordinary circumstances to procure, in the perfectly fresh state, and with the perfect freedom from disease which are indispensable, such a supply of material from the human subject as will even approximately suffice for his purpose. Therefore, as material

Material selected.

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Weight of ox brains.

Preparation of brains.

for the present very large inquiry, ox brains* have in most part been preferred; and of these more than a thousand have been used. Five brains weigh on an average 1,780 grms., or eight weigh six pounds. They are washed once and freed from clotted blood. They are next carefully skinned, the arachnoid and pia mater being removed by means of fine anatomical forceps. When the brains are entire they may be skinned in the ordinary anatomical manner, which employs two pairs of forceps, worked simultaneously and antagonistically by both hands of the operator. When, however, the brains are much broken up, each piece must be held in one hand while being freed from membranes with the other. The skinned parts are again rinsed in water, and then placed in water for a short time; next placed upon a sieve to drain, and then submerged in methylated alcohol of 85 °/₀ by weight in volume strength, previously purified by distillation over tartaric acid. Great care is necessary to supply a sufficient amount of alcohol, so that the brains may be quickly dehydrated and hardened. For if the alcohol is too dilute, or becomes too dilute by being insufficient in quantity, the brains remain soft and unworkable, and decompose with a fetid odour. For the same reason all brains, before submersion in alcohol, must be broken up, or sliced into small pieces, so that they can be easily penetrated by the alcohol. This is required even when strong alcohol is used, as this is liable to harden the outer shell merely, and leave the inside of the brain to soften and decompose.

Submersion in alcohol.

First extracts.

The washing and submersion in water probably remove small quantities of extractives and soluble salts, besides the blood, and must therefore be carried out with care. The solutions so obtained are thrown away, but the alcoholic solutions in which the brains have been hardened are purified from albumen by boiling and filtration, freed from spirit by distillation, and evaporated to the consistence of extracts on the water bath. They are to be considered as water-extracts, and are mostly free from specific brain substances, and only yield extractives and salts and other matters, which will be described in the relative chapters.

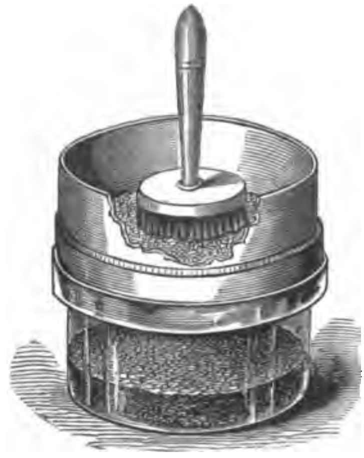
Mincing the brain.

When the brains are well hardened in the alcohol, which frequently requires the repeated removal of the watery spirit and substitution of fresh strong spirit, they are passed through a rotary mincing machine, and the minced portions are again mixed up with strong alcohol. This pulp is now worked through a very fine hair sieve, having 144 meshes to the square inch, and each of the twelve strands of hair crossing the square inch in one direction, being composed of eight single horse hairs; the sieve stands upon a glass-receiver, a so-called fern glass, in such a manner that it cannot move, and no matter which passes the sieve can be lost. The trituration on the sieve is effected by a strong circular furniture brush, which is incessantly rotated over the sieve by the hands of a workman. When passed through the sieve

Comminution through hair sieve.

* The ox brains as obtained from the butcher are generally much suffused with blood. This arises from the mode in which the animals are slaughtered; a blow is inflicted upon the frontal region with the pole-axe, whereby a piece of skull is punched in and pressed into the brain. Immediate unconsciousness and paralysis is the result. In addition to this the slaughterer destroys the spinal reflex-centres by introducing a cane through the hole in the skull into the spinal canal and destroying the marrow by stirring it about. The skull is afterwards cloven, and the brain taken out in two halves. Where animals are killed by the Jewish method of cutting a gash across the throat and bleeding the animal to death, the brain may be removed uninjured, and may even be washed *in situ* by injecting water through the *carotids*. But this proceeding is laborious, and offers no advantages as regards the chemical examination of the brain. For investigations of the spinal marrow, however, animals so killed are alone suitable, as by the pole-axe and cane method the spinal marrow is almost entirely destroyed.

the brain is in the state of a very fine pulp or purrée, and is ready for extraction. All other modes of comminution which have been



Sieve on Fern-Glass and Rubbing Brush for Comminuting Brains.

recommended are less useful than the foregoing; they are either inefficient or slow and laborious; in particular trituration in a mortar with a pestle is very inefficient. All methods of comminution which do not reduce the brain to the finest possible pulp, or smooth paste, must be rejected, as from imperfectly comminuted brains the immediate principles are necessarily most imperfectly extracted.

Bad modes of comminution.

The smooth paste of brain matter is now mixed with a considerable amount of alcohol of 85 °/₀, and heated in a well-tinned large saucepan over a gas lamp by a star-burner or any other heat source, while being stirred with a wooden rod without intermission. When it has reached the temperature of 45° the mixture is removed, and immediately poured on a filtering cloth stretched and tied over the top of a large earthenware jar or pan. The filter is covered with a wooden cover. When the liquid has percolated, the pulp is removed from the cloth with a flat spoon, and again placed in the saucepan, mixed with spirit, heated to 45° while being stirred, and again placed upon the same filter as before. This operation is repeated in all about five times, when the brain matter is exhausted of all matters which alcohol will dissolve. The matter is now tied up in the cloth and pressed in a screw press. It comes out as a solid, somewhat elastic cake of *albuminous* or *insoluble residue*, of which the analysis and description will be given in a future chapter. I have always arrested the heating at 45°, because it has been so frequently stated that when brain matters are heated beyond they decompose. But since I know the behaviour of the isolated brain matters, I have great doubts about the correctness of this statement, and should in a given case think it quite safe to boil the mixture. But the low heat is certainly efficient and convenient, and need not therefore be overstepped. For the same reason a saucepan of cast-iron of about three gallons capacity is preferable to any other vessel of tin or glass. The earthenware jars or pans should be of a capacity of from 12 to 15 gallons. I have found them most useful, and carried on all operations from the soaking and hardening to the last filtration of the buttery precipitate with their aid.

Extraction with warm alcohol. **Vessels used.** **Insoluble albuminous residue.** **Degree of heat employed.** **Advantages of certain vessels.**

The alcoholic extracts are all united, and allowed to cool during from 12 to 24 hours. In hot weather the cooling must be assisted by placing

Treatment of alcoholic extract.

The precipitate.

Filtration.

the jars into a tub and surrounding it with cold water and ice. Two such tubs are conveniently produced by cutting a port wine pipe into two equal halves. The extracts during cooling deposit a large amount of *white crystalline and granular precipitate*, which adheres to the sides and covers the bottom of the vessel, while the alcohol is perfectly clear, though coloured slightly yellow. The whole is filtered through a cloth stretched over a pan, and when the entire precipitate is collected on the cloth, and has been condensed by stirring

Pressing.

with a spoon, the cloth is removed, tied up, and placed into the screw-press, and all mother-liquor thus removed. When taken out of the cloth the precipitate presents itself as a hard white cake, which can be broken into pieces, and constitutes the particular white matter of Vauquelin, and will in the following always be signalised as *white matter*.

White matter.

When the abreviations *w. m.* occur in the description of any preparation, they indicate that the preparation has been extracted from this white matter. I shall not describe this white matter any further, nor have I instituted any experiments upon it such as Vauquelin made, because it is evidently a very complicated mixture, containing nearly

Substances contained in white matter.

the whole of the substances to be described as the cerebrines, stearoconotes, cholesterines, kephalines, myelines, and lecithines, and small quantities of other matters. The processes by which these substances may be extracted will be given lower down, after the description of the treatment of the alcoholic extract has been

Keeping qualities of white matter.

completed. Here it may yet be stated that the white matter can be preserved in stoppered bottles in a cool place and protected from light almost unchanged for a very long time. In contact with absolute alcohol it also remains unchanged, though gradually yielding a yellow extract; but in contact with ether it yields kephaline to the latter, which is quickly oxydised into a red substance having a green fluorescence; this effect seems due to the peroxyde of hydrogen produced during the oxydation of the ether. I have therefore limited the use of ether to the most necessary operations, and then cause the substances to pass through these with great despatch, so that this oxydising effect of the ether is as far as possible avoided.

Alcoholic filtrate distilled.

The Alcoholic Filtrate from the White Matter is now placed in a capacious tinned copper still, and a great part of the alcohol is distilled off. When a certain degree of concentration has been obtained, which is determined by experience, the hot liquid is thrown into a pan, and again allowed to cool, assisted if necessary with cold water or ice. It now deposits a second quantity of matter, which is less solid and more coloured than the first and after filtration remains on the cloth as a semi-solid plastic substance, to which I have given the name of the

Buttery matter.

buttery matter. This can only be freed from mother liquor by manipulation with a spoon, and must not be pressed too hard, as it is liable

Substances contained in buttery matter.

to pass through the meshes of the cloth. The buttery matter consists of much cholesterine, lecithine, little myeline, kephaloidine, and some cerebrine, and small quantities of other matters; the substances are therefore qualitatively mainly the same as in the white matter, but they are present in entirely different proportions. The buttery matter also keeps well in a bottle by itself, or in the presence of alcohol, but should also not be kept long in ether.

Alcoholic filtrate from buttery.

The Alcoholic Filtrate from the Buttery is again distilled so long as good spirit passes over and no precipitate ensues in the fluid. When these conditions are exhausted it is placed in a large dish on a water bath and evaporated. At a certain period *oily drops* make their appearance, which adhere to the sides or float in the fluid, and unite to larger round globular masses. They separate easily while the fluid is

hot, but when the fluid cools they swell, become flaky and distributed in the fluid and cannot be filtered. They are best separated while hot by a separating funnel, to which they adhere, while the fluid sinks down; or they may be collected on a paper filter on a hot funnel. This matter has received in my laboratory the title of the LAST OILY, by which it will be signalised in this essay. It consists mainly of phosphorised bodies with little cholesterine, and some peculiar not yet accurately defined matters, amongst them oleate and margarate of ethyle.

Last oily matter.

The Filtrate from last Oily constitutes the ultimate mother liquor and contains all matters from the brain which are highly soluble in water, such as the salts, the extractives, and soluble immediate principles to be described. This liquid is evaporated on the water bath to the consistence of a thin extractive and placed in bottles until further examined as will be described. While the preparation accumulates it is well to keep the extract covered with some absolute alcohol to prevent the formation of mould on its surface.

Filtrate from last oily, last mother liquor.

Treatment of the White Matter.—The white matter is now to be extracted with cold absolute alcohol. The alcohol must be cold to leave as much as possible of the cerebrine, cholesterine, kephaline, and myeline undissolved, and to dissolve all the lecithine; and it must be absolute so that the cerebrine and kephaline may not become hydrated in any way, but rather more dry under the influence of the alcohol. The best mode of mixing the alcohol and white matter intimately is by the hands in a wide earthenware pan. While the workman is kneading this mixture no light or fire is permitted in the laboratory. The extraction is so regulated that the same alcohol is used to extract several portions of white matter in succession, so that most of the alcohol employed comes away nearly saturated with what it can dissolve. As the extraction proceeds the white matter becomes plastic and yields but little to alcohol, and then the extraction is interrupted, the residue thrown on a cloth, drained and dried.

Treatment of white matter.

Mixing with the hands.

Treatment of the Alcoholic Solution.—The alcoholic solution is first exposed to frost, when mostly a white deposit of myeline is observed, which may be filtered off on a funnel surrounded with freezing mixture. The alcoholic filtrate is then reduced in bulk by distillation, and again exposed to frost, and this treatment is repeated. In this manner several deposits are obtained, which become more and more fluid and oily, until at last the solution is a thick oil, which when exposed to the air dries out to a plastic waxy mass of a neutral ether mixed with much cholesterine and little kephaline and myeline, and lecithine.

Exposure to frost.

Myeline deposited.

From the successive deposits some myeline may now and then be obtained in a crystalline form, by resolution in alcohol, refreezing, washing with ether, but by solvents alone the bulks of these matters cannot be separated. It is therefore best to treat the alcoholic solution as follows:—

Isolation of small deposits of myeline.

Platinum Chloride Treatment of the Alcoholic Solution.—To the alcoholic solution freshly prepared pure absolute alcoholic solution of platinic chloride is added as long as a precipitate is thereby produced. The voluminous yellow precipitate is thrown upon a filter, washed with absolute alcohol, removed from the filter into a bottle, and shaken with absolute alcohol, again placed on a filter, drained upon a cloth and without being allowed to become dry or waxy treated as follows:—

$PtCl_4$ Treatment.

Treatment of the Platinic Chloride Precipitate.—It is placed in a large stoppered bottle, mixed with a large volume of ether, and shaken from time to time during several hours, until there are no lumps perceived in the bottom of the bottle, and the contents consist of a fine yellow powder and an orange-coloured solution only. Then powder and solu-

Treatment of $PtCl_4$ precipitate with ether.

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tion are separated by filtration. The salt on the filter has to be repeatedly removed from the filter, to be shaken with ether in a bottle, and to be refiltered until pure; washing on the filter alone is almost impracticable. The insoluble salt constitutes *myeline platinic chloride*, with its modifications to be described lower down. It easily dries in air to a yellow somewhat waxy mass, which is easily powdered. The ether solutions and washings are united, concentrated to a small bulk by distillation from the water bath, and then precipitated by the addition of much absolute alcohol. The precipitate is washed on the filter, also by shaking in a bottle with alcohol, again filtered, drained on blotting paper, and placed on porcelain or glass dishes, in a vacuum over sulphuric acid to dry. This soluble in ether salt constitutes probably *lecithin platinic chloride* with its modifications to be described lower down. It contains, however, some kephaline, from which it has to be freed by a special process to be described under the chapter which treats of the purification of this precipitate.

Insoluble in ether salt myeline Pt Cl^4. Treatment of ether solutions and washings. Soluble in ether salt and Pt Cl^4.

Treatment of alcoholic mother liquor

Alcoholic Filtrates from the Platinic Chloride Precipitates.—These are coloured yellow, and on standing deposit cholesterine in crystals, and a trifling quantity of platinic compounds. They are filtered, concentrated and treated with hydrothion and water. The water removes *chlorides*, which may be investigated as regards the bases. The platinic sulphide mostly retains *organic matter*, which must be extracted by alcohol and ether, applied cold and boiling. Besides residues of the principal matters already extracted they contain *peculiar neutral bodies* in small quantities, which are not fats commonly known, perhaps oleate and margarate of ethyle, and require a more elaborate study hereafter. Neutral fats so called, trimargarine, tristearine, tripalmitine, trioleine, if at all present in brain substance, are so in extremely small, hardly appreciable quantities.

Peculiar neutral bodies, not fats

Treatment of the White Matter from which Lecithine and some Myeline has been extracted by cold absolute Alcohol.

Extraction with ether.

This matter is to be extracted with ether. For this purpose it must again be kneaded in a pan, this time with ether, by the hands of workmen. All shaking in bottles, trituration in mortars, is perfectly futile. With operations in ether the presence of light or fire in the laboratory is still more to be avoided than with operations in alcohol. The extraction with ether causes the previously plastic white matter to assume a grumous pulverulent consistency, and to yield a matter to the ether, which quickly becomes red.

Difficult problem.

Kephaline.—The filtration of the solution from the fine white insoluble matter is one of the greatest difficulties of the whole series of operations. I find the following process the most effectual. The mixture is thrown on a cloth in a funnel surrounded with freezing mixture, and as much liquid is allowed to percolate as may. When the cloth is full and ceases to filter it is tied up, and with the pasty mass placed under a screw press. The white milky matter now squirts in all directions, unless the press is worked very slowly, and a constant current of pure ether is directed upon the outside of the cloth. In this manner, with much labour, requiring the constant attention of three operators, the matters are at last separated into a hard residue of *cerebrines* and *myelines*, and into a solution containing *all cholesterine*, *all kephaline*, and *some myeline.*

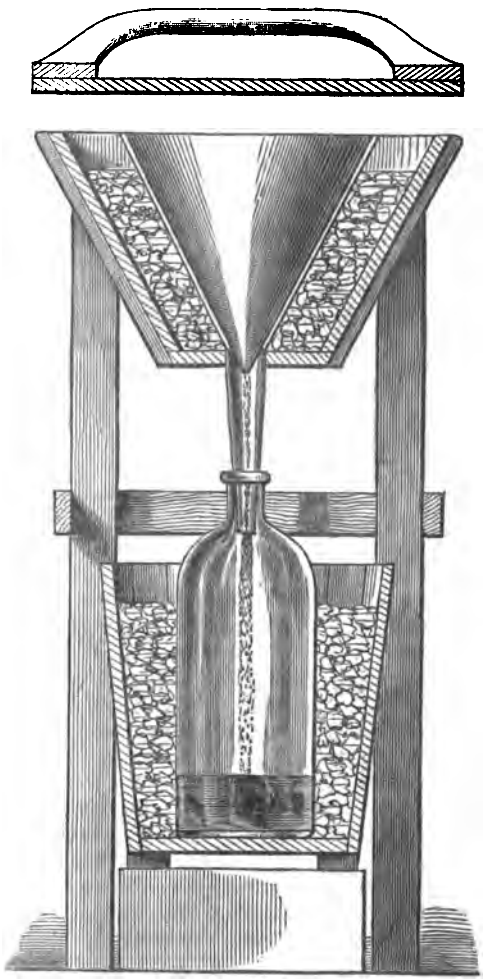
Pressing.

Separation of kephaline from cerebrines, &c.

Treatment of the solid Residue for the Separation of the Cerebrines from Myeline.—These residues when dry are intermediate between wax

Extraction of myeline by hot ether.

and gum arabic in appearance. They consist in the main of the cerebrines, with the stearoconotes, and some myeline. The latter has to be extracted with hot ether, in which the two former are quite insoluble. The extraction has to be continued until the residual matter of cerebrine, &c., *is free from phosphorus*. This requires large quantities of ether, as it quickly evaporates during filtration on a funnel surrounded by warm water. The receiving bottle stands in a pail surrounded with ice, so that the hot ether is immediately cooled. It immediately deposits the myeline as a white powder, which is afterwards separated by filtration on the funnel surrounded with freezing



Filtering Stand of Wood with Funnel which may be surrounded with Warm water or freezing Mixture.

Distillation of myeline solution.

mixture. When the funnel is not surrounded with freezing mixture. much myeline re-dissolves in the warmer ether. This portion is only obtained by distillation of the ether, and is not so pure as the portion deposited from the ether on cooling. The myeline is purified further as will be described under the chapter relating to it, and the cerebrines are

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separated from stearoconote and from each other, and from any remaining myeline as will be described under the headings relating to them. The myeline may also be extracted with cold pure benzole, in which the nitrogenised bodies are quite insoluble.

Freezing out cholesterine and myeline.

Treatment of the Ether Solution containing Kephaline and Cholesterine, separated by Filtration from the Cerebrine, &c.—This solution is colored red and fluoresces green. It is concentrated by distillation from the water bath, placed in stoppered bottles, and exposed to frost in an ice and salt mixture. If concentrated it becomes solid with crystals of cholesterine and granules of myeline; in this case it must be thawed until pulpy, filtered on the funnel surrounded with ice, and the filtrate again frozen. In any case the *solution must be frozen and filtered cold until it remains quite clear, even in the sharpest freezing mixture.* In that case most of the kephaline remains in solution, and retains only little cholesterine and very little myeline. The cholesterine which crystallises out, contains myeline and little kephaline, from both of which it may be separated as will be described under the chapter relating to the purification of cholesterine.

Precipitation of kephaline by alcohol.

The ether solution containing the kephaline is now mixed with twice its bulk, or as much as may be required to effect complete precipitation, of absolute alcohol; a voluminous, whitish, flaky, adhesive precipitate ensues, which becomes darker as it condenses; this is *crude kephaline.* The mother liquor when clear after some standing, is decanted, the kephaline is rinsed with alcohol, collected, manipulated with a glass rod or spatula so as to remove alcohol enclosed in its meshes, spread on a glass dish and dried in vacuo, to be purified as will be described under the chapter relating to kephaline.

Precipitation of matters by cadmic chloride.

The ether alcohol mother liquor is treated with an alcoholic solution of cadmic chloride, whereby a mixture of compounds of kephaline and myeline with this salt falls down, which is collected, washed, and further purified, decomposed and identified as will be described. The mother liquor from these cadmium salts is distilled to dryness, treated with water for the removal of cadmic chloride, and the insoluble part is again boiled with small quantities of alcohol,

Cholesterine and neutral peculiar matters.

when cholesterine is obtained in crystals, and a quantity of neutral matter, part of which is oily, part solid; both will be described in a separate chapter.

Ether process applied to white matter

Another Process for separating White Matter into its Constituents.—In many of my earlier investigations I used the following process which for the purpose of abbreviation I will term "ether process, W.M." This yields the cerebrines very quickly and directly, and leaves little myeline with the cerebrines. It also yields kephaline, but in lesser quantity as much remains in the mother liquors. But the myeline, lecithine, and cholesterine remain in the ultimate mother liquor, and can be separated only by cadmic or platinic chloride. The precipitates obtained are more complicated than in the first process. But under given conditions the process possesses advantages and is therefore at all events here described as an alternative second in value.

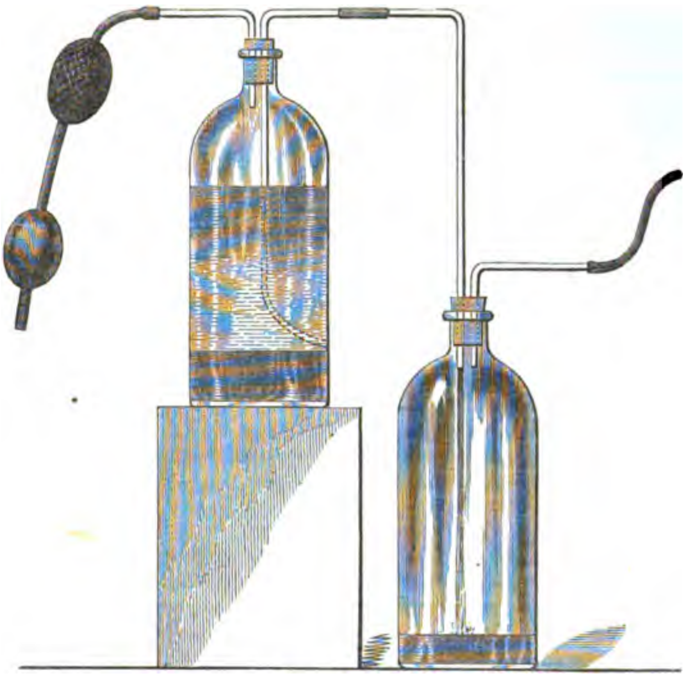
Extraction of W.M. with ether.

The white matter is fully extracted with ether in stoppered bottles, with the precaution of using the same ether for several portions of white matter so as to obtain saturated solutions. All secondary solutions and washings are concentrated by the still. The whole of the solutions are now exposed in bottles (stoppered) to a strong freezing mixture of ice and salt, and the clear coloured ether is quickly siphoned

Description of siphons.

off the dense white deposit. All siphons are of glass tube, with movable caoutchouc joints, and mounted in corks, so that they can be applied to the bottle to be emptied on one side and to the bottle to be filled on the

other side, air tight, and be started either by blowing (with the air bellows) or by suction at the opposite end. The inner limb of the



Arrangement of Siphon for decanting by Pressure and Suction.

siphon is so curved as to be near the side of the bottle and easily visible, its point is directed sideways to prevent an upward rush of deposited matter.

This apparatus gives to the operator full power to start and arrest the flow of the ether whenever he finds it desirable, and enables him to regulate the suction pipe, and so take off the last portions of ether above the deposit, without losing much ether or being molested by it. When the principal mother liquor is removed, pure ether is thrown upon the deposit which is again frozen. The deposit is much less soluble in pure ether than in the mixture of dissolved matters, a peculiarity shewn by almost all brain substances. The deposit, when dense, frequently forms a firm cake at the bottom of the bottle, which comes off as a round disk. These "*first deposits by frost from ether extracts of white matter*" are separated into cerebrine and myeline, as will be described lower down. Perhaps the most massive and substantial quantities of myeline can be obtained from them, that can be obtained at all without the circuitous route of combination with metallic salts.

Cerebrine and myeline deposited by frost.

When the ether extracts give no further deposits on exposure to renewed freezing mixtures, they are treated with absolute alcohol until all *kephaline* is precipitated. If the alcohol be watery, even slightly, say of 80 to 90 $^{\circ}/_{\circ}$ strength, the deposit contains much cholesterine, particularly if the ether solution is concentrated. Absolute alcohol should therefore be always taken as well as absolute ether for these operations; many other reasons which will appear in the sequel support this desideratum to the extent of making it an absolute condition of perfect success.

Precipitation by alcohol of kephaline, &c.

Absolute ether and alcohol required pure.

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Both ether and alcohol should be pure, *i.e.*, not made from methylated spirit, but from pure spirit, and always be specially tested for purity and strength.

Precipitation of mother liquor with cadmic chloride.

The kephaline so precipitated is much less pure than that obtained in the first process, and requires, therefore, more purification by the processes to be described. The ether-alcohol mother liquor is now treated with cadmic chloride dissolved in alcohol, so long as a *precipitate* takes place. The precipitate is filtered off on a cloth, pressed hard, and immediately placed in ether. A cadmium salt dissolves, and will be described in the following as "soluble in ether cadmium salt from white matter after kephaline." It consists of kephaline with another phosphorised matter combined with cadmic chloride. Another salt remains insoluble in ether, and will be described in the following as "insoluble in ether cadmium salt from white matter after kephaline." It consists mainly of myeline combined with cadmic chloride. The immediate principles can be obtained from these cadmium precipitates only with difficulty and by laborious and long processes, and therefore they are less useful, if applied at this stage of the operation, than might at first sight be expected; but they enable the operator to completely extract from the phosphorised substances the cholesterine which remains in the mother liquors. The mother liquors are distilled in the water bath until all ether is removed. On cooling they then deposit cholesterine in crystals, nearly pure. After further evaporation they deposit more cholesterine, mixed with some cadmium salt; ultimately they leave a mixture of cholesterine and neutral peculiar matters, to be isolated and purified as will be described.

Two salts, one soluble the other insoluble in ether.

Treatment of ether alcohol mother liquor.

Buttery treated with alcohol.

Treatment of the Buttery Matter.—The buttery matter is kneaded with absolute alcohol in a pan, and allowed to extract during 24 hours. The alcohol is then renewed and the kneading repeated frequently until the undissolved matter appears as an adhesive, semi-solid mobile substance, yielding little or nothing to alcohol. This insoluble matter is mainly *kephaloidine*, with *cholesterine*, little *myeline*, and less *cerebrine*. It is treated with absolute ether, in which kephaloidine easily dissolves; myeline dissolves a little, leaving the bulk of myeline and cerebrine as a white undissolved mass. The latter are filtered off and washed. The ether solution is exposed to a freezing mixture until it remains permanently clear after filtration and renewed exposure. It is then mixed with sufficient absolute alcohol to precipitate all matters which will go down. When the mixture is clear the ether alcohol is decanted, the precipitate collected, rinsed with alcohol, spread on glass dishes, and exposed in a vacuum to dry. It constitutes *kephaloidine*, which must be purified, as will be described under the chapter relating to this substance. The ether alcohol mother liquor of kephaloidine is treated with platinic chloride, or cadmic chloride, and the relative precipitates are separated by ether, so as to yield soluble in ether salt (kephaloidine and lecithine salt), and insoluble in ether salt (myeline salt). These salts must be further treated like those obtained from white matter. They are small in quantity.

Insoluble matters separated and treated with ether.

Kephaloidine isolated.

Alcohol extract of buttery.

The alcoholic extract of the buttery matter can be treated by gradual concentration and exposure to freezing mixtures, when myeline and cholesterine, ultimately cholesterine alone, are deposited; but the process offers no advantage except preliminary information, as each fraction of deposit has to be treated in the same manner in which I now treat the entire solution. It is mixed with as much solution in absolute alcohol of pure platinic chloride as will effect complete precipitation. The voluminous precipitate is filtered and washed with absolute alcohol, particularly by removal from filter and shaking in a bottle with the

Precipitation with $PtCl_4$.

washing alcohol and re-filtering. It is then drained on bibulous paper, without being permitted to become dry and waxy, or soft and pasty. It is next treated with a large volume of absolute ether until it is differentiated into a fine yellow powder and an orange-coloured solution. These are separated by filtration; the pulverulent matter is washed with ether to exhaustion, which requires its removal from the filter and shaking with ether in a stoppered bottle, and re-filtration, repeated more than once. Ultimately this precipitate dries easily in air, and becomes somewhat waxy, but is easily powdered. It constitutes *myeline-platinic-chloride*. The orange-coloured ether solution is concentrated, when on exposure to cold it will frequently deposit the soluble salt as a solid mass, but it is better to precipitate the solution by absolute alcohol, filter, wash with alcohol, and shake therewith in a bottle two or three times, drain on bibulous paper, and dry in vacuo. The latter precipitate constitutes probably *lecithine-platinic-chloride*. It is, however, less pure than the myeline salt, as it necessarily contains some kephaloidine, from which it has to be purified as will be described under the paragraph to be given to this account.

Treatment of Pt Cl⁴ precipitate with ether.

Myeline Pt Cl⁴ from buttery.

Lecithine Pt Cl₄ from buttery

The alcoholic mother liquor from which all matters precipitable by platinic chloride have been removed on standing deposits some cholesterine and a little platinum compound. It is concentrated by distillation, and on cooling deposits much cholesterine. Platinum is now precipitated by hydrothion, and the precipitate extracted with water, which removes hydrochloric acid. From the black precipitate matters are extracted by alcohol and ether, which yield cholesterine and the neutral bodies already referred to; but it is probable that the distillation of the first alcohol in presence of the platinic chloride affects some of the matters, so as to change them more or less from their original properties.

Alcoholic mother liquor.

Yields cholesterine.

Treatment of the last oily.—This is easily soluble in alcohol and ether, without residue. It is simply treated in alcohol solution with platinic chloride, and mostly yields only salt soluble in ether (lecithine? platinic chloride); sometimes also myeline salt, and sometimes it decomposes during treatment, yielding a resinous platinum salt insoluble in most reagents, and not yet any further studied. It is an accidental product. The mother liquor yields cholesterine and neutral matters, but only in small quantity, being probably oleate and margarate of ethyle. The buttery matter has also been subjected to ether treatment, but without any advantage, and this treatment, which can be easily deduced from the ether treatment of the white matter, as an analogy, need not here be any further described.

Treatment of last oily.

Pt Cl₄, from last oily.

Ether treatment, process applied to buttery.

We have thus separated the brain into the following immediate principles or mixtures thereof:—

Principles of brain matter.

1. First extractives (by soaking alcohol).
2. Insoluble albuminous residue.
3. White matter, containing:—
    - *a.* Kephaline (with varieties and compounds).
    - *b.* Myeline (with varieties and compounds).
    - *c.* Lecithine (with varieties and compounds) (?).
    - *d.* Cholesterine (varieties problematical).
    - *e.* Cerebrines (several varieties).
    - *f.* Neutral lipoid matters, probably ethers (several, solid and fluid).
4. Buttery matter, containing:—
    - *a.* Kephaloidine (with varieties and compounds).
    - *b.* Myeline (with varieties and compounds).
    - *c.* Lecithine (with varieties and compounds) (?).
    - *d.* Cholesterine (varieties problematical).
    - *e.* Cerebrines (several varieties).
    - *f.* Neutral lipoid matters, probably ethers (several, solid and fluid).

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5. Last oily matter, containing :—
   a. Lecithine (with varieties and compounds) (?).
   b. Cholesterine (varieties problematical).
   c. Etherised lipoid matters (several, solid and fluid)
6. Ultimate watery extract of brain, containing :—
   a. Extractives.
   b. Nitrogenous principles.
   c. Hydrocarbons.
   d. Organic acids and salts.
   e. Inorganic salts.

Explanation of definitions in summary list.

In the foregoing descriptions of processes I have, for the purpose of brevity, spoken of the crude immediate principles which were isolated as if they consisted of a single body each ; but in the summary list just given I have added to most of the names of these compounds an enlarged definition, by which not only *the pure principle*, but also *varieties of it*, and *compounds of it* are said to have been isolated in one and the same operation. This is strictly the case, as will be seen, for example, in the account of kephaline hereafter to be given; but it may be at once stated that the pure immediate principle which gives rise to the name constitutes the great bulk of each preparation; that this bulk is relatively greatly increased by the removal during the process of purification of matters in chemical combination with a smaller portion of the immediate principle, and that the varieties are very similar in type to the principal matter, and whenever they cannot be separated absolutely their nature and quantity can be ascertained by very good approximations. Where matters are so similar in properties as kephaline and kephaloidine, a complete separation of the entire quantity of each from the other is not easily effected, but a quantity of each can be obtained pure from the other, and from the results obtained by their chemical study the composition of mixtures in any proportions can be derived. The immediate principles above enumerated may be arranged in the following groups :—

Arrangement in groups of immediate principles.

Group of Principles containing Five Elements, C, H, N, S, O.— This may be termed *the group of sulphurised or albuminous principles.* It includes albumen and small quantities of histo-genetic substances.

Group of Principles containing Five Elements, C, H, N, P, O.— This may be termed *the group of phosphorised principles.* It includes:—

Kephaline, with varieties and compounds.
Myeline, with varieties and compounds.
Lecithine, with varieties and compounds (?).

It is at present uncertain whether any of the solid and fluid neutral lipoid matters belong to this group.

Group of Principles containing Four Elements, C, H, N, O.—This may be termed *the group of nitrogenised principles.* It includes :—

Cerebrine in its several varieties.
Kerasine in its several varieties.
Phrenosine in its several varieties.
Extractive acids, and secretory acids, and their salts, such as uric acid, and congeners.
Neutral principles, such as urea and amido-acids.

Group of Principles containing Three Elements, C, H, O.—This may be termed the *group of oxygenated principles.* It includes :—

Cholesterine, with any varieties. } Alcohols.
Hydrocarbons, such as inosite. }
Organic acids, such as lactic, formic, &c.
Fats and fatty acids, which if not regularly found in health, are certainly present in disease.

Group of Inorganic Principles, including both acids and bases, and salts, either free or in combination with many of the foregoing organic principles. This includes :—

Sulphuric acid.
Hydrochloric acid, and as Cl in chlorides.
Phosphoric acid.
Carbonic acid.

Potash Soda Ammonia Lime Magnesia Copper Iron Manganese	In combination with immediate principles, forming their bases, or in combination with phosphoric acid, and attached to immediate principles as phosphates, or in combination with mineral acids, as free mineral salts in the juices and extracts.

Alumina, silica, fluorine (doubtful).

As the albuminous matters from the brain, when once isolated, offer no specific differences from albuminous matters of the body in general, and as their study, while in combination in the fully constructed brain, can only be carried on with advantage after the matters peculiar to or highly prevalent in brain substance are fully known, I have not given much time to this group, although information as to its bearing in mass, and as to the inorganic matters combined with it in mass, has been obtained; this is to be reserved for expansion in future researches. In the present essay I propose to communicate only those researches which bear upon *the group of phosphorised* and the *group of nitrogenised bodies*, and that *portion of the group of inorganic principles* which directly combines with the bodies of these groups. I may, however, state that much information on the principles constituting all other groups, as well as much material towards their study, has been collected in the course of these researches.

II.—DESCRIPTION OF CERTAIN CHIEF PRINCIPLES WHICH HAVE BEEN ISOLATED.

A.—Group of Phosphorised Principles.

CONTENTS.

General properties.

General Properties of the Phosphorised Principles.—This group comprises kephaline, kephaloidine, myeline, and lecithine, and their congeners and compounds. All these bodies have certain properties in common, which point to some similarity in chemical constitution; by other peculiarities again, they are sharply distinguished from each other. *They are all soluble in water in a certain manner and measure.*

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When they are in the dry state, and are placed in pure water, they sink to the bottom, and are at once wetted by the water. Thus, their specific gravity is shown to be greater than that of water, and by this and the faculty of being wetted, they are sharply distinguished from the fats or fatty acids, but assimilated to the soaps, as the older authors correctly stated. When they have remained in the water for a short time, they begin to swell, to become transparent at the thin margins of the particles, and covered with a loose layer all over their surface. This on agitation is easily detached, and floats in clouds in the liquid; the clouds diffuse themselves indefinitely throughout the whole of the water, and if enough water is present, the mixture is frequently shaken and some time is given, the particles of solid matter disappear entirely and form a turbid solution of very peculiar appearance. As will be seen hereafter in particular, these solutions can by no mechanical means be clarified, yet they are solutions and pass through many layers of the finest Swedish filtering paper; no particles can be distinguished by high powers of the microscope, yet they must be there and consequently so small as to be beyond the reach of optical definition as single particles. They exhibit their presence, however, by iridescence in the case of myeline and lecithine, and by reflecting polarised light in all cases. These solutions, therefore, resemble somewhat the cold solutions of soaps, and the emulsions produced by solid fatty acids with neutral phosphates; the emulsion produced by vegetable seeds (almonds) with water, &c.; but they differ from milk and emulsion of fats and gum by there being no particles visible. Moreover, emulsions are supposed to require the presence of two agents besides water, whereas these brain substances give this peculiar solution with mere water; they are not decomposed, as the soaps are, into acid and alkaline salt, as they are not salts, but form these solutions in the free and uncombined, but also in the combined state. I can give no better definition of this peculiar condition than by describing it as *a state of imperfect or incomplete solution*, a stage intermediate between the solid and the fluid state of matter. Those who do not coincide in this description may term the solution an "emulsion," if that conveys any definite idea, or a state of the finest subdivision of particles with peculiar attraction of these particles to water, and consequent repulsion of particles from each other. This latter part of the question I shall have to consider at greater length when I come to discuss the dependence of the structure of the brain upon the chemical and physical characters of its ingredients. For the present purpose it suffices to sum up that these phosphorised bodies have all an extreme attraction for water, swell in it, and ultimately form a nearly perfect solution. By this means they afford good opportunities for mechanical and chemical purification now to be described.

Manner of dissolving.

Solution cannot be clarified.

Similarity to soaps and emulsions.

Definition of imperfect solution.

Deposition of Impurities.—The solutions on standing deposit any mechanical impurities, and any cholesterine contained in the matters dissolving crystallises out and sinks to the bottom. Any excess of the matters beyond saturation is also deposited, as well as the less soluble compounds. If any cerebrine were with the matters it would deposit as a thick gelatinous matter. All solutions therefore produced as above, and which experience has shown me, should not contain above one per cent. of the matters, must be allowed to stand for a day or two, in order that these insoluble impurities and admixtures may be deposited. The pure solution is then removed with the syphon from the deposit; the solution is filtered, and the deposit further exhausted with water.

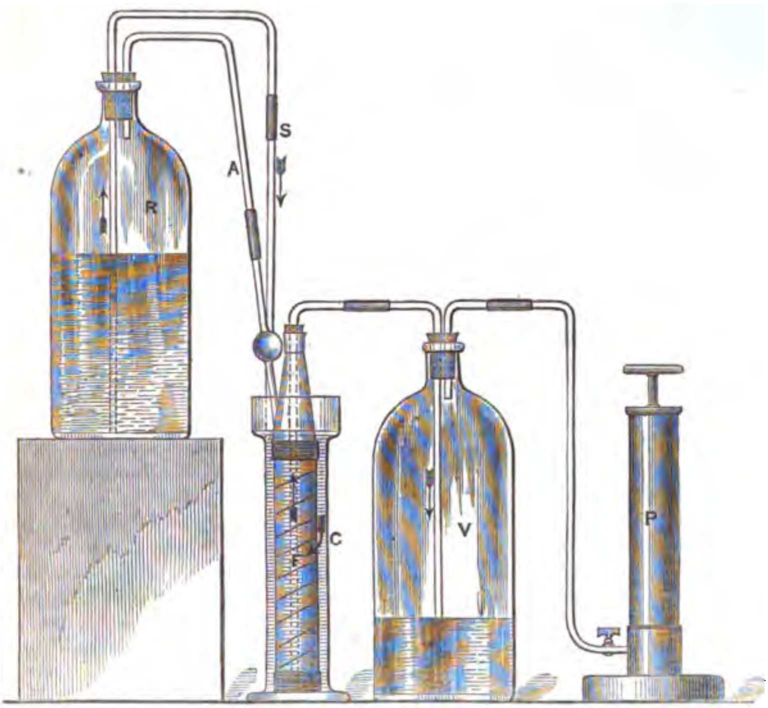
Deposition of impurities.

Decanting by syphon.

Filtration of the Watery Solutions of the Phosphorised Matters.—When the solutions are placed on an ordinary filter of paper, a portion passes by gravitation, but the pores of the paper gradually become ob-

Filtration of aqueous solutions.

structed and filtration ceases. It is therefore necessary to expedite filtration by the aid of pressure. For this purpose I have constructed a new apparatus in which a vacuum draws the liquid to be filtered into a hollow cylinder surrounded with paper.



Apparatus for Filtration by Air-pressure.

The filter F is a hollow cylinder of silver-plate pierced like a fine sieve, and covered with a six-fold roll of Swedish filtering paper, made secure at the top and bottom by a ring of string, which also runs spirally over the whole paper. This stands in a glass cylinder C which contains the fluid to be filtered and is always kept full by a perpetual siphon S, drawing the liquid from the reserve bottle R; as frequently as the fluid in the wide upper part of the cylinder sinks below the oblique end of the air tube A, which is wide and provided with a bulb, air is admitted by A into R and the siphon acts. The bottle receiving the filtrate V is evacuated of air gradually by means of the air pump P. The tube which draws the filtered liquid from the cavity of the cylinder goes to the bottom of the cylinder, so that nearly the whole of the filtered liquid can at any time be drawn into V.

Such a cylinder, about a foot long and four inches in circumference, will, with a pressure on C of 70 centimetres of mercury, filter a Winchester quart full of one per cent. solution of phosphorised matter per day; the more, the purer the substance is, the less, the more cholesterine and cerebrine it contains. Sometimes only 100 cc. are filtered per hour. In such a case a coarser filtering paper should be rolled over the Swedish to collect the coarsest particles and prevent them from getting upon the Swedish paper. After some hours filtration becomes slow and ultimately ceases entirely; then the paper is found covered with a gelatinous mass of undissolved matter and impurities. These may be rinsed off and

Quantity filtered in time.

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again extracted and filtered; but I have mostly found the matter so small in quantity that I have discharged it with the paper. Such a filter, with two changes of paper per day, may be going night and day, and if all corks are air tight, which is easily effected by applying hot paraffine to them, requires very little attention except a few strokes of the pump from time to time. When the substances previous to their solution in water were very pure, they left no vestige of cholesterine crystals, or of cerebrine on the filter. The filtered fluids are still opaque, those from kephaline more colored, those from myeline and lecithine of a milky whiteness with the blue iridescence. When a good filtration had been effected, a second filtration effected no improvement and was quickly accomplished. In this manner all phosphorised matters used for cardinal preparations were passed through the process of watery solution and filtration.

Filtered fluids.

The process offers peculiar advantages for each of the three varieties of phosphorised principles, but is essential only for the purification of myeline from cerebrine; this separation is effected more conveniently, if not more completely, than by means of ether. Kephaline scarcely ever retains any cholesterine, but myeline always does, unless it has passed through the $Pt\,Cl_4$, or $Cd\,Cl_2$ process.

Solubility in ether.

All the Phosphorised Matters are soluble in Ether, but in very different Proportions.—Kephaline dissolves in this reagent in almost any quantity; lecithine only less than kephaline; but myeline is very little soluble in cold ether, more in hot ether, and is instantaneously deposited from the ether as it cools.

Solubility in alcohol.

All the Phosphorised Matters are soluble in Alcohol.—Lecithine in all proportions in hot absolute alcohol, less in cold; kephaline is almost insoluble in cold alcohol, more soluble in hot, almost entirely deposited on cooling; myeline, however, is little soluble in cold alcohol, largely soluble in hot, and is deposited on cooling in a crystallised state, and in such quantities that the fluid becomes filled with crystals. It will thus be seen that while water offers no means for the separation of these substances from each other, ether and alcohol offer great advantages, which have indeed been utilised in the construction of the method for their separation above described.

(*a.*) *Sub-Group of the Kephalines.*

CONTENTS.

Purification by resolution.

Kephaline.—$C_{42}\,H_{79}\,N\,P\,O_{13}$.

Purification.—The crude kephaline obtained by the primary operations is dried under the air pump over sulphuric acid. It must be

repeatedly taken out, and flattened out in a mortar, and again dried, before it becomes dry and brittle and can be powdered. Resolution in absolute ether, reprecipitation by absolute alcohol, and redrying causes a great improvement, but also much loss.

Filtration of the solution in water.

The dry substance is then dissolved in pure water, 10 grms. in the litre, and after complete solution by agitation in a stoppered bottle, is allowed to deposit less soluble salts and impurities, decanted or syphoned from these, and then filtered by pressure as described.

Treatment with HCl.

The filtered solution is now treated with enough hydrochloric acid to effect complete precipitation of all kephaline as hydrochlorate, a salt which appears in voluminous flakes, and on shaking collects on the surface of the liquid. (This precipitation, like others to be related, affords a good criterion of the previously dissolved state of the substance.) The mother liquor is drawn from underneath the precipitate with a siphon; fresh water is poured on the precipitate, and the whole is now placed upon a paper filter or cloth, and washed with water, until it begins to swell and dissolve. At that point it is found that all HCl is washed out, and that only *pure hydrated kephaline* remains on the filter. This was expressly proved by analysis in several cases, but more especially in the following experiment.

Washing with water.

Experiment proving Expulsion of Hydrochloric Acid from Kephaline by Water.

Experiment proving expulsion of H Cl from kephaline by water.

Half a litre of a weak kephaline solution was precipitated by H Cl and filtered; the precipitate on filter was replaced in 500cc. of water to test its solubility, and was found insoluble, but the water contained free H Cl. It was again filtered, and after solution had ran through, absolute alcohol was blown on the precipitate; this became adhesive, and the solution refused to filter. The alcohol and precipitate were transferred to a beaker, and the whole was gently warmed in a water bath to a temperature not much above 60°. The precipitate fused, but dissolved very sparingly, apparently the less the more the alcohol made the precipitate anhydrous. The alcoholic solution was now filtered off warm, and the undissolved portion of the precipitate taken up with ether. The solution so obtained was of a colour resembling ordinary kephaline in ether, and was poured into the alcoholic solution. The precipitate which ensued was fawn coloured, adhesive, and leathery; it was isolated, washed with absolute alcohol, the mother liquor being squeezed out of it, then pressed and dried in air-pump. When dry it weighed 0·6290 gram. The whole was analysed for chlorine as follows. It was heated to dryness in a strong solution of pure soda, with carbonate and nitre added, and the mass was burned. The fused mass was dissolved in dilute nitric acid, and the solution tested with argentic nitrate. No precipitate occurred, showing that *the body obtained in this process is not a hydrochlorate,* but probably kephaline in a purified state. This latter probability is raised to a certainty by the following experiments.

Traces of ammonia.

Examination of the Bases and Salts which are in combination with Kephaline, after Filtration of its Aqueous Solution.—The solution of hydrochloric acid and other matters filtered from the precipitated kephaline was evaporated to dryness. A portion was then boiled with solution of baryta, when traces of ammonia were evolved. The rest of the residue was then ignited in a platinum dish to destroy all traces of organic matter. The ash was slightly molten, and only partially soluble in water, but easily soluble in water slightly acidified with hydrochloric acid. The solution was filtered from a trace of

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The precipitate contains iron.

Calcium. Phosphoric acid.

carbon, and treated with excess of ammonia, whereupon an abundant precipitate of *earthy salts* fell down, and the solution assumed a *deep blue colour*. Precipitate and solution were separated by filtration. The precipitate dissolved readily in a little HCl, forming a slightly red solution, indicating presence of *iron*, which was confirmed by the sulphocyanide test. In another portion of the solution dilute sulphuric acid gave an abundant precipitate of gypsum, showing presence of *calcium*. In another portion the molybdate test showed the presence of *phosphoric acid*. To the remaining portion a few drops of ferric chloride were added, then sodic carbonate nearly to neutrality, and lastly, excess of barytic carbonate. This mixture was allowed to stand, filtered and filtrate, freed from excess of baryta by sulphuric acid, filtered and filtrate after supersaturation with ammonia, gave a great precipitate with ammonium oxalate, insoluble in acetic acid, showing presence of much calcium. The filtrate from this calcic oxalate on concentration and treatment with ammonia, ammonic chloride, and sodic phosphate gave the precipitate characteristic of *magnesium*. The precipitate produced above by barytic carbonate was boiled with excess of pure soda, and filtrate warmed with ammonic chloride, when only a turbidity was produced, indicating the *absence* of *aluminium*.

Calcium confirmed.

Magnesium.

No aluminium.

Lime not in combination with P^2O_5.

The alkaline filtrate from the foregoing precipitate by ammonia was tested for lime by oxalate, when a considerable precipitate was produced, showing the *presence of lime uncombined with phosphoric acid*, and which must therefore have been in combination with part of the kephaline. The blue solution was again filtered from calcic oxalate, which had been entirely precipitated, and acidified with hydrochloric acid. The *copper* was precipitated by hydrothion, the filtrate evaporated to dryness, ignited, and the residue tested for alkalies. This residue was considerable, surmounting in quantity or bulk the bases previously removed. It was fusible with ease, and on solidification became white and crystalline, but interspersed with many red particles of ferric oxyde. The fusion showed it to be mainly *potassic chloride*, but there was also some *sodic chloride* present, as indicated by flame reaction, and the ferric oxyde which had escaped precipitation by excess of ammonia.

Copper.

Potassium sodium.

Summary.

It is therefore proved that the kephaline obtained by the alcohol and ether processes, and purification by solution in water and filtration, consists of the following ingredients:

Kephaline in the free state.

Kephaline combined with ammonium, sodium, potassium, calcium, iron, copper, and with calcic and magnesic phosphates.

This experience was repeated a great number of times on, in the aggregate, several hundred grammes of dry kephaline; the calcic and potassic salts were always found prevailing greatly in quantity over the others, none were ever absent. Although I have not compared the total of the neutralising power of the bases with the total of the acid combining power of the kephaline, by direct quantitative experiment, I am sure that much kephaline must have been present in the free state, as will appear from future developments concerning the combining and dissociating powers of this body.

Attempted clarification and decolorisation of kephaline.

Experiments intended to effect a Clarification and Decolorisation of Watery and Ethereal Solutions of Kephaline.

White of egg does not curdle in kephaline solutions.

To a solution of one gram kephaline in 100 c.c. of water, 5 c.c. of filtered fresh *white of egg* were added, and the mixture was heated in a flask in the water bath; it remained turbid and no separation of coagulated

albumen took place. The mixture had a faintly alkaline reaction. On addition of a drop of acetic acid to the heated mixture a copious precipitate ensued, which enclosed both kephaline and albumen (the kephaline solution by itself, cold, is only partially or imperfectly precipitated by the same acetic acid). By filtration a perfectly clear liquid was obtained, which was no longer precipitated by baryta water or platinic chloride, and not changed by boiling. Consequently, all albumen and all kephaline were removed together from the solution and perhaps in part combined. Cold absolute alcohol in large quantity extracted all or nearly all kephaline from the albumen, and on distillation left it *perfectly white.* The albumen, on the other hand, was, after washing with alcohol and ether, in a finely divided pulverulent state, and not hard nor horny. This process is therefore useful for preparing snow-white kephaline, which must however not again be brought into contact with ether, as that would immediately cause it to become coloured under the influence of oxydation.

Acetic acid curdles. mixture. Kephalate of albumen.

White kephaline. Porous albumen.

This experience bears directly upon the treatment of albuminous solutions from animal liquids; for it must now be studied whether they do not all contain kephaline and allied bodies, and whether the phosphorus so often found in them is not due to the admixture of a quantity of kephaline.

Question whether all animal albumens contain kephaline.

Influence of Animal Charcoal on Water Solution of Kephaline.—To a solution of 1 grm. kephaline in 100 c.c. of water, 2 grms. of pure animal charcoal were added, the mixture shaken, and then subjected to the vacuum filter. A little fluid passed, which became at last quite clear. A portion of the last clearest, collected by itself and tested, was found to be almost pure water; for hydrochloric acid, platinic chloride, baryta hydrate, and lead acetate, produced the very feeblest precipitates only, while the original solution was made solid by the same precipitants. The animal charcoal therefore retained the kephaline, and when isolated and extracted with alcohol yielded it up to that solvent. This experience, as well as that made with albumen, shows that the watery solution of kephaline cannot be clarified by these agents, if indeed they do not show also that the condition of kephaline is one of suspension and not of true solution. That, however, charcoal has a special attraction for kephaline, such as it also exhibits towards other ammonium bases and alkaloids of undoubted solubility in water, is shown by the following experiment.

Animal charcoal retains kephaline.

Yields it to alcohol.

Bearing of Kephaline in Ether with Charcoal.—A concentrated solution of kephaline in ether was treated with much animal charcoal, in order to be decolorised. The object was but partially obtained. The charcoal, after filtration and washing, was found to retain much kephaline, which was extracted by boiling absolute alcohol, and from this deposited on cooling in a *perfectly white state.* The solution deposited more on spontaneous evaporation. Both were tested and identified as kephaline.

Charcoal extracts kephaline from ether.

Yields it to alcohol.

Kephaline therefore can be removed from watery solution by charcoal and curdling albumen, and again extracted from these substances by hot or cold alcohol in large quantity, and obtained from these solutions in a perfectly white state.

Summary.

Ultimate Analysis of Kephaline.—A specimen of highly purified kephaline was passed through the water-filtration and hydrochloric acid process; it amounted to four litres of one per cent. solution, and after re-solution in ether and precipitation by alcohol left about 30 grms. dry matter. It was thoroughly dried in vacuo over sulphuric acid, being frequently triturated, and ultimately reduced to a fine powder. Carbon

Elementary analysis.

C and H determination.

Nitrogen.

and hydrogen were determined by combustion with lead chromate and copper turnings. 0·4622 grm. gave 1·017 grm. CO_2, equal to 0·2772 grm. carbon or 60·00 °/$_o$ carbon ; and 0·391 grm. H_2O, equal to 9·399 °/$_o$ hydrogen.

Nitrogen was determined by volume, the bichromate and carbonate mixture being used for production of carbonic acid gas. 0·544 grm. gave 8·0 c.c. gas at 15° C and 763 m.m. B. Height of K H O column =150 m.m. equal to 15·33 m.m. mercury. Total 28 m.m. deducted from 763 leaves 735 m.m. $\frac{8 \times 273 \times 735}{288 \times 760}$ = 7·33 c.c. normal=1·68°/$_o$ nitrogen.

Phosphorus.

Phosphorus was determined by evaporating the substance with solution of pure soda, made from metallic sodium, mixed with carbonate and nitre, to dryness, slowly deflagrating, &c., and determining phosphoric acid by magnesia method. 0·9574 grm. gave 0·1468 grm. magnesium pyrophosphate ($Mg_2P_2O_7$), equal to 4·27 °/$_o$ phosphorus.

Thus we have the following per-centages and atoms :—

Found.		÷ by at. wgt.	÷ by N = 1	Theory. Atoms.			Theory. Per cents.
C	60·00	5·00	41·7	42	C	504	60·28
H	9·39	9·39	78·3	79	H	79	9·44
N	1·68	·12	1·0		N	14	1·67
P	4·27	·13	1·0		P	31	3·70
O	24·66	1·54	12·9	13	O	208	24·88
	100·00						

Formula.

leading to formula $C_{42}H_{79}NPO_{13}$.

We shall see hereafter that this formula is supported by the results of the analysis of a number of other preparations, being partial or complete compounds of kephaline, of which the organic matter always has the composition of the free substance ; and by the results of a series of chemolytic experiments the sums of the cleavage products of which also lead to this formula.

Combines with water.

Combinations of Kephaline.—In water kephaline swells and forms an emulsion, ultimately an imperfect turbid solution. Its affinity for water is very great, and the last quantity of water is expelled from it in the vacuum only with great difficulty and after a long time. From a watery solution or mixture it cannot be extracted by ether, as the liquids form an emulsion which persists even after a portion of the ether has separated from the water. This emulsion is very thick, like paste, white like milky water, and practically unmanageable. When a drop or a few drops of a concentrated ether solution are allowed to fall into a test tube full of water, the mixture is at once transformed into a white jelly, which is so firm that the tube can be turned upside down without anything flowing out of it. Solutions of kephaline in water on standing do not decompose or become mouldy, even in the course of some weeks.

Ether makes a jelly ; no extract obtained.

Solubility in alcohol.

Cold absolute alcohol dissolves a little kephaline, more on boiling, and deposits a part on cooling in white flocks. 100 parts absolute alcohol at 17° C. dissolve seven parts kephaline ; at boiling heat of the alcohol nine parts, of which two parts are deposited on cooling. When an excess of kephaline is boiled with an insufficient amount of alcohol,

the part which remains insoluble does not seem to undergo any change, for it retains its solubility in ether and precipitability by alcohol and other reactions.

Solubility in ether.

In ether kephaline, when not too much hydrated, is highly soluble; when dry it is soluble in anhydrous ether in almost any proportions; it does not crystallise from this solution, and cannot be made to deposit as from a mother liquor. It is precipitated from the ether solution by an equal or greater volume of alcohol in white clouds, which combine to clots, and ultimately forms a firm substance, which becomes at first plastic, and then dries in vacuo to a hard brittle mass. The ether solution becomes quickly red in transmitted light, and fluoresces with a fine green color. No other phosphorised or other brain ingredient shows this peculiarity except kephaloidine.

Alcohol precipitates ether solution.

Fluorescence.

Solubility in benzole.

Solubility of Kephaline in Benzole.—A specimen, thrice precipitated from ether by alcohol, and when last in ether, exposed during 24 hours in ice to a temperature of 0°, proved soluble in cold benzole, and very soluble in hot. It formed a yellow solution. A sample in a test-tube exposed to frost gave no deposit. The addition of alcohol to the benzole solution produced a slight precipitate, insoluble in excess of alcohol, but soluble in excess of benzole, and soluble on heating. Benzole can therefore not be used, like ether, for the purification of kephaline.

Precipitated by alcohol from benzole.

Reactions in test tubes.

Reactions of the Aqueous Solution of Kephaline.—A one per cent. solution, filtered by air-pressure through three-fold Swedish filter paper, was used.

1. Hydrochloric acid gives a bulky curdy precipitate, slightly yellow, and after isolation soluble in ether, *not* precipitated by alcohol from its ethereal solution. In the filtrate from this hydrochloric acid precipitate platinic chloride produces the merest opacity. But from the ethereal solution of the H Cl precipitate alcoholic Pt Cl_4 throws down a precipitate, which is soluble in ether, and reprecipated by alcohol. — H Cl.
2. Sulphuric acid produces a precipitate like that produced by H Cl. — H S O.
3. Nitric acid the same as the previous acids. — H N O_3
4. Baryta water produces a bulky curdy precipitate. — Ba H^2 O^2.
5. Lime water produces a similar precipitate, but it does not separate like the Ba H_2 O_2 precipitate. — Ca H^2 O_2.
6. Cadmic chloride, curdy precipitate which readily coalesces. — Cd Cl_2.
7. Zinc chloride, similar to Cd Cl_2. — Zn Cl_2.
8. Mercuric nitrate produces a dense precipitate, which is insoluble in nitric acid, but colored slightly yellow thereby, heat being evolved. The precipitate is sometimes rose red, and in adhesive flakes. Washed and allowed to stand with water it becomes again white, ropy, and adhesive, and soft, and on being shaken easily dissolves in water in the manner of the original kephaline. The mercuric nitrate seems therefore to be separated by water from kephaline in the same manner as other salts and acids are. — Hg N O_3.
9. Baryum chloride produces a good dense flaky precipitate. Immediately after isolation it is insoluble in water, insoluble in alcohol, but easily soluble in ether, and apparently reprecipitated by alcohol. This reprecipitated matter was proved to contain baryum. Some special experiments with this compound will be related hereafter. — Ba Cl_2.
10. Calcium chloride acts like Ba Cl_2. — Ca Cl_2.
11. Platinic chloride produces a bulky precipitate. — Pt Cl^4.
12. Ammonia makes solution a little turbid; no precipitate. — N H_4 H O.
13. Platinic chloride mixed with H Cl produces a very well-defined precipitate. — Pt Cl_4 + H Cl.

$Mg\,Cl_2$. 14. Magnesium chloride, a very precise immediate precipitate.

$Fe_2\,Cl_6$. 15. Ferric chloride, a yellowish turbidity ; imperfect precipitate.

$Ur\,N\,O_3$. 16. Uranic nitrate, a white turbidity, and precipitate imperfect.

Br. 17. Watery bromine produces a bulky precipitate, nearly white soluble in caustic potash ; acetic acid added to this agai, liberates the precipitate. Chloroform added to this mixture produces a chloroform solution of Br at the bottom, containing the excess of reagent, and an impracticable white emulsion on the top.

$Cu\,(N\,O_3)_2$. 18. Cupric nitrate

$Cu\,Cl_2$. 19. Cupric chloride

$Cu\,S\,O_4$. 20. Cupric sulphate

$Cu\,(C_2\,H_3\,O_2)_2$. 21. Cupric acetate

(18–21) All produce perfect precipitates of a greenish white colour.

$Hg\,Cl_2$. 22. Mercuric chloride makes the solution very turbid, but no precipitate.

$Hg\,(C_2\,H_3\,O_2)_2$. 23. Mercuric acetate, immediate complete precipitate.

$Ag\,N\,O_3$. 24. Argentic nitrate, immediate complete precipitate, darkening a little when exposed to sunlight.

$Au\,Cl_3$. 25. Auric chloride, and a drop of H Cl, immediate precipitate, which blackens over night.

$Sb_2\,Cl_6$. 26. Antimonic chloride, a very bulky precise white precipitate.

$Sn\,Cl_2$. 27. Stannous chloride, a white flaky complete precipitate.

$Sn\,Cl_4$. 28. Stannic chloride, a precipitate and turbid solution.

Tannin. 29. Tannin in water, no particular reaction.

Picric acid. 30. Picric acid, a turbidity, but no manageable precipitate.

$As_2\,O_3$. 31. Arsenious acid, a precipitate and turbidity.

$As_2\,O_5$. 32. Arsenic acid, a very complete immediate precipitate.

$H_3\,P\,O_4$. 33. Phosphoric acid, a very complete immediate precipitate.

Basic Pb acetate. 34. Basic lead acetate, a precipitate and very turbid solution; no perfect separation.

In none of the foregoing reactions was any artificial heat employed, but they were all made at the ordinary temperature.

It was found that most of these precipitates could not be washed with water without losing either acid or base, or salt, with which they were combined. But most of them remained insoluble in water until the point of purity was reached, when the kephaline either dissolved in the pure water, or clogged the filtering paper.

Dialysis of kephaline.

Dialysis of Kephaline.—A solution of five grams of crude kephaline was dissolved in 500 c. c. of water, and formed a white thick liquid, from which some cholesterine crystallised on standing. It was then placed on a dialyser of parchment paper. A trace of kephaline passed into the water, but so small was the quantity, that no chemical operation could be undertaken with it.

Kephaline does, practically, not dialyse, but may perhaps act as a colloid, and allow its impurities to pass out into the water.

Kephaline cadmic chloride salt.

Kephaline Cadmic Chloride Salt, prepared from Kephaline purified from bases by H Cl Process.—Two litres of a filtered one per cent. solution were precipitated by dilute H Cl. The mother liquor was drawn off, and the precipitate washed by agitation with water. The washing water was again drawn off, and watery solution of cadmic chloride added, which caused great condensation of the precipitate. The liquor was again drawn off, and the precipitate shaken violently with a great quantity of alcohol containing alcoholic cadmic chloride. Thus the precipitate was condensed to a viscous mass, from which the mother liquor was drawn off, and the alcohol entirely removed by careful manipulation. After draining, the precipitate was dissolved in ether,

and to the ethereal solution was added alcoholic cadmic chloride, cautiously, till a slight permanent precipitate was perceived. This was removed by filtration, and the brilliant fluorescent filtrate precipitated by absolute alcohol. The viscous mass was again drained from all alcohol by pressure with a glass rod. Redissolved in ether, it formed a perfectly clear solution, which was reprecipitated by absolute alcohol, when the compound came down in an almost pulverulent state. It was thrown on a filter, washed with absolute alcohol, then removed on a glass dish and placed under a dryer, then in a vacuum over sulphuric acid, and frequently removed to be powdered in a mortar, and ultimately finely pulverised. It was then subjected to elementary analysis, which yielded the following results:

Elementary Analysis.

Carbon and hydrogen.

1. Carbon and hydrogen were determined by combustion with $Pb\,Cr\,O_4$, and copper turnings. 0·4630 gram. gave 0·9100 $C\,O_2$, equal to 53·603 % carbon, and 0·355 H_2O, equal to 8·519 % hydrogen.

Nitrogen

2. Nitrogen determined as gas. 0·5504 grm. gave 6.5 c.c. N, at 14° C and 765 m.m. B. Height of K H O column = 146 m.m. These elements give the calculation $\frac{6\cdot5\times273\times739}{287\times760}=6\cdot01$c.c.N normal = to 1·37% nitrogen.

Chlorine, cadmium, and phosphorus.

3. Chlorine, cadmium, and phosphorus were determined by fusion with caustic soda, nitre, and carbonate, with great caution; solution of salts in acid, precipitation of cadmium by hydrothion, and conversion into carbonate. Chlorine and phosphorus were determined in filtrate from cadmic sulphide by the usual methods. 1·0022 grm. salt gave 0·0742 Cd O, equal to 6·47 % cadmium. Further, 0·1682 grm. Ag Cl, equal to 4·15 % chlorine, and 0·1268 grm. $Mg_2\,P_2\,O_7$, equal to 3·54 % phosphorus. The cadmium and chlorine were in the relation of $Cd : Cl_2$, inasmuch as 4·15 parts chlorine require 6·54 parts cadmium.

Summary of results—

Summary.

C	53·603	89·38
H	8·519	
N	1·37	
P	3·54	
O	22·35	
Cd	6·47	10·62
Cl	4·15	
	100·00	100·00

Calculation shows that the kephaline is not completely saturated with $Cd\,Cl_2$, ; that about four parts out of nine are uncombined. For the formula, derived from the organic matter with P as 1, *i.e.*, $C_{42}\,H_{79}\,N\,P\,O_{13}$, $Cd\,Cl_2$ yields the equation:—

$$\underbrace{C_{42}\,H_{79}\,N\,P\,O_{13},\,Cd\,Cl_2}_{1019} \;:\; \underbrace{Cd\,Cl_2}_{183} \;::\; 100 \;:\; 17\cdot95,$$

whereas only 10·62 % $Cd\,Cl_2$ were found.

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Deducting $Cd\,Cl_2$, and calculating per cents. of elements in organic body, we get—

		÷ by At. Wgts.	÷ by P as 1.	At. Wgts.
C	59·97	4·99	41·6	504
H	9·53	9·53	79·4	79
N	1·53	·11	1·0	14
P	3·96	·12	1·0	31
O	25·00	1·56	13·0	208
				836

leading to formula $C_{42}\,H_{79}\,N\,P\,O_{13}$, with an atomic weight of 836, thus fully sustaining the composition of the free substance.

As 10 parts of $Cd\,Cl_2$, supposed to be combined with a molecule of kephaline correspond to 59 parts of compound, about 40 per cent. of the above substance may have been free kephaline.

The very weak chemical affinities of kephaline are here exhibited in a striking manner; $Cd\,Cl_2$ was brought into contact with it at various periods, and yet could not be retained in combination. This is due to the fact that $Cd\,Cl_2$ cannot be dissolved in absolute, but only in somewhat watery alcohol; and even little water decomposes the compound, and carries the $Cd\,Cl_2$ away, as will be shown by special experiment hereafter.

First preparation.

Bearing of Kephaline with Hydrochloric Acid and Platinic Chloride.—About three litres of 1 °/₀ solution, which by the deposition of the insoluble part and filtration had lost much of the 1 °/₀ originally dissolved, were treated with a mixture of $H\,Cl$ and $Pt\,Cl_4$ in slight excess. A bulky yellowish white curdy precipitate ensued, and rose to the surface; it was allowed to contract, and the yellow mother liquor drawn from beneath it by a syphon. Absolute alcohol, equal in bulk to the precipitate, was now poured upon it, and the mixture violently shaken. This caused a further contraction of the precipitate, indicated by lesser bulk, increase of the yellow colour, and production of adhesiveness. The alcoholic liquid was again syphoned off, and another quantity of absolute alcohol was now poured on the precipitate, and the mixture violently shaken. The precipitate thereby became deep yellow, adhering to the glass, and so contracted that the liquor could be poured off quite clear. The precipitate was now treated with a minimum of ether, in which it proved quickly and entirely soluble. On filtration, nothing whatever remained on the filter. An equal volume of absolute alcohol was added to the ether solution, whereby almost the whole of the salt was precipitated. The latter was freed from mother liquor by careful manipulation with a glass rod, redissolved in absolute ether, which gave a brilliant solution requiring no filtration, and this was reprecipitated by absolute alcohol in equal volume, added in a thin stream while the liquid was being stirred. The mother liquor was poured off; the precipitate, which immediately became brittle and hard on rinsing with absolute alcohol, was drained from alcohol and placed over sulphuric acid in the vacuum.

Solution in ether.

Second preparation.

Second Preparation.—Another amount of the same body was made from four litres of a 1 °/₀ solution, in the same way, with this difference, that whereas in the first case the precipitate was washed with alcohol directly, in *this* case two washing with water were carried out before the application of alcohol. This was done in order to test the effect of water upon the compound desired to be produced. It was found that the dry body treated with ether and alcohol like the first

preparation contained only a trace of platinum and a vestige of chlorine, both elements being too small in quantity for accurate determination.

Contains only a trace of $Pt\,Cl_4$.

Preparations united.

Both preparations were therefore united, and it was sought to combine them with platinic chloride under circumstances, where the influence of water was as much as possible excluded. (It must be remembered that solid platinic chloride contains six atoms of hydration water, which it necessarily carries into all its solutions.) They were dissolved in ether and an ethereal solution of $Pt\,Cl_4$ was added, then precipitated with absolute alcohol. Again dissolved in ether, and treatment with $Pt\,Cl_4$ repeated. Ultimately the precipitate was dissolved in pure ether, reprecipitated by pure alcohol, and dried in vacuo.

Analyses.

Analyses.—1·581 grm. deflagrated with the usual precautions yielded 0·0568 grm. metallic platinum, equal to 3·592 °/₀ Pt, and 0·2088 grm. Ag Cl, equal to 3·265 °/₀ Cl.

If the platinum had been accompanied by only as much chlorine as corresponds to tetrachloride, 2·58 °/₀ Cl should have been found. By calculation we find that there is one fifth of Cl more than corresponds to this proportion, viz., 1 Pt : 5 Cl=3·592 Pt : 3·22 Cl.

A compound of the presumable formula :

$2\,(C_{42}\,H_{79}\,N\,P\,O_{13}) + 2\,Cl + Pt\,Cl_4$ with an atomic weight of 2083 requires 9·5 °/₀ Pt and 10·2 Cl. Consequently, the platinic chloride compound comprises about one third of the kephaline, of which two-thirds are uncombined.

Summary.

It is thus seen that although kephaline is most completely precipitated by $Pt\,Cl_4$ from its watery solution, yet by the process of solution and precipitation with solvents in which $Pt\,Cl_4$ is soluble, most of the $Pt\,Cl_4$ is extracted from the combination, and lost in the mother liquors, just as it is almost entirely extracted from the same precipitate by water. In short, the acids, bases, and metallic salts which easily combine with kephaline, when they are present in excess, are rapidly separated from it by solvents in which they themselves are readily soluble.

Theoretical considerations.

Chemically speaking these results are disappointingly negative, inasmuch as they refuse to furnish the ordinary means for determining the atomic weight and for finding guarantees of purity of preparations. But physiologically these features are of the greatest interest, inasmuch as they show us a marvellous diversity of power of reaction of kephaline, by entering into and out of combination according to external circumstances. When the combinants are offered in a concentrated state they are retained, when the liquids which carry the combinants (blood, serum, cerebrospinal fluid) become again diluted, the combined matters must again pass into solution and travel further. Thus every change of chemical composition of the juices of the body must necessarily and powerfully affect the condition of the brain and nerves, and of all tissues and cells containing their specific ingredients.

Condition of labile equilibrium.

Kephaline and and $Ba\,Cl_2$.

Kephaline and Baryum Chloride.—Two litres of a 1 °/₀ watery filtered solution of kephaline were precipitated by $Ba\,Cl_2$, the mother liquor was drawn off, the precipitate agitated with water containing $Ba\,Cl_2$, then washed with pure water, and finally on a filter where the washing with water was repeated until the washings were free from baryum and chlorine. The enormously hydrated and swelled frothy precipitate was placed under a drier over sulphuric acid and dried, being frequently stirred and moved, ultimately powdered in a mortar to change the drying surface of the hardening matter and the drying completed in vacuo.

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Analysis showed that the kephaline was almost pure, and retained only traces of baric chloride.

Analyses. Heating to 100° C.

Decompositions of Kephaline.—When pure kephaline in the perfectly dry state is heated in a water oven to between 90° and 100° it fuses into a dark red transparent viscid oil. It becomes solid again on cooling, but retains a viscosity, so as to adhere to the fingers, which it did not before it was heated. Treated with water the heated and cooled kephaline swells again and gradually dissolves, but is darker coloured, so that some slight degree of decomposition or of oxydation seems to have taken place.

Ignition.

When heated to higher temperatures it gives out much heavy strongly smelling inflammable vapour, which partially burns with formation of much soot. Ultimately a bulky charcoal is left, which cannot by ordinary heating in platinum vessels be entirely destroyed, as it is soaked with phosphoric acid. It cannot be entirely burned even after the principal quantity of phosphoric anhydride has been extracted with water. Complete combustion is effected only in the presence of nitre.

H_2SO_4+sugar test.

With concentrated sulphuric acid dry kephaline in fine particles immediately assumes a dark red brown colour, which gradually becomes nearly black. When sugar and sulphuric acid are allowed to act upon kephaline a reaction similar to the one given by bile acids is gradually engendered. But the process essentially requires time, during which the mixture passes through a stage of dark brown colour, until a deep purple is at last attained. But this colour is never so pure or beautiful as that obtained with cerebrine, myeline, or the bile acids. It is therefore probable that a decomposition of the kephaline has to be effected before the reaction is attained.

Chemolysis by Na H O.

Chemolysis of Kephaline by Caustic Soda. First Experiment.—A watery solution containing 30 grms. of pure kephaline, filtered, &c., was precipitated by H Cl; the mother liquor was syphoned off, and the residue washed once with distilled water. The H Cl necessarily yet contained in the precipitate was disregarded, as not interfering with future operations. The pulpy deposit was put into a flask, and a solution of 5 grams. crystallised soda hydrate added. The precipitate disappeared on agitation, forming first a gelatinous, later a fluid solution, similar to the filtered kephaline solution. The solution was now placed in a bath and heated gently for nine hours. During the process it was observed that skins formed on the surface similar to membranes on milk while being heated (? May such a phenomenon have given rise to the surmise that the yolk of egg contained "caseine"?) On cooling the liquid formed a gelatinous cake, consisting of viscous curds set in a thinner fluid. Next day the mixture was boiled during nine hours on a sand bath. Bumping was mitigated by dropping a spiral of platinum into the fluid. Great frothing ensued, which was opposed by a funnel fixed upon the top of the flask by a cork. The funnel was supported by a stand to prevent its breaking the flask in the event of itself breaking. (Eventually both funnel and flask cracked, the latter at the base of the neck.) After this boiling the liquid was still turbid, became gelatinous, viscid, and set on cooling, and covered by a membrane, and was supposed to be decomposed. On commotion it showed the wavy glistening appearance of soaps, and when at repose in a beaker formed folds as from a tubular membrane sinking.

Reactions of soapy solution.

Reactions of the Soapy Solution and Mixture.—It was insoluble in water, and not further precipitated thereby. It was curdled by cold alcohol, dissolved by hot, leaving, however, some particles undissolved, which proved soluble in ether.

Not precipitated by concentrated sodium chloride solution, *i.e.*, not salted out. Acetic acid added to this last sodium mixture causes curdling, and on boiling the curds collect on the top without fusing. Consequently, none of the known fatty acids are present in any quantity. Ether added to this solution readily dissolves the whole of the precipitate. Acetic acid alone, without any Na Cl added to original solution, produces a flocculent precipitate, which cannot be filtered clear, and when half filtered clogs the paper. From this mixture the precipitate can apparently not readily be extracted by ether. The watery fluid remains turbid, and the ether colourless. Hydrochloric acid causes an immediate curdy precipitate in the soapy mixture ; on boiling the precipitate does not fuse or coalesce, although it contracts it remains flaky. Some of the precipitate was shaken up with cold absolute alcohol, when much of it readily dissolved, and the filtered solution gave pulverulent precipitates with baryta water, and lead acetate. The entire quantity of the soap was now treated with hydrochloric acid, until a strongly acid reaction was attained, when a whitish yellow precipitate fell, and the fluid lost its viscosity. Filtration through Swedish paper was effected ; the precipitate on filter was washed with water, and the filtrate was evaporated on water bath.

Precipitation by H Cl.

The acids.

1. *The Precipitate of Fatty Acids on the Filter* was washed, and became very adhesive yet fatty; boiled in water it did not fuse, but agglutinised a little ; nothing like oil or fused fatty acid appeared. Warmed on paper it did not fuse like fat, and gave only a very slight grease stain; most of it remained slightly glistening on the surface, even when heated until brown. The matter had a fine, smooth, greasy touch between the fingers, and seemed like a fatty acid in a hydrated swelled state. It dissolved easily in cold absolute alcohol, leaving a quantity of adhesive dark matter undissolved. As it was treated on the filter, two litres of absolute alcohol were requisite to take up all soluble matters.

Acids soluble in alcohol.

2. *The Acids soluble in Alcohol.*—The solution showed a feeble green fluorescence ; it was filtered from a slight secondary deposit of insoluble acid. Alcoholic acetate of lead was now added, which produced a bulky nearly white precipitate. This was washed with absolute alcohol, drained on paper, dried, and treated with ether. It was entirely insoluble in ether, and constitutes

Kephalophosphate of lead.

a. Kephalophosphate of lead, so named from being a phosphorized acid obtained from kephaline, more complicated than glycerophosphoric acid. The total quantity of salt obtained weighed 6·2 grms. Powdered and dried at 95° C, it baked together a little on surface, but when stirred remained pulverulent.

Determination of Lead.—0·6534 grm. carefully ignited, during which salt swelled much, became black, and evolved inflammable gases, left 0·2214 grm. white residue, apparently free from oxyde and metallic lead, and insoluble in acetic acid ; soluble in nitric acid, and containing phosphoric acid. This acid is, therefore, a compound of glycerophosphoric and another acid, and would, perhaps, by continued chemolysis with excess of free alkali, split up into those acids. The pyrophosphate found corresponds to 0·1558 grm., lead equal to 23·84 % Pb in the salt. This leads to 661 as the atomic weight of the new acid (H_2 not added), and deducting 172 for supposed glycerophosphoric acid, to 489 as atomic weight of additional organic body.

C and H Determinations.—Substance dried at 80° C. 0·4144 grm. gave 0·7330 grm. CO_2 = 48·262 % C, and 0·2990 grm. H_2O = 7·990 % H.

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A combustion for nitrogen gave only a trace of permanent gas, so that the substance is proved to be free from nitrogen.

Phosphorus calculated from the Pb pyrophosphate found=3·572 °/₀ P.

	Found in 100.	÷ by At. Wgts	÷ by P = 1.
C	48·262	4·022	35·3
H	7·990	7·990	70·1
Pb	23·840	0·1151	1·01
P	3·572	0·1139	1·00
O	16·336	1·021	8·96
	100·000		

leading to formula $C_{35} H_{70} Pb P O_9$.

Deducting the lead, and calculating the 76·16 °/₀ of organic matter as 100, we get—

		÷ by At. Wgts.	÷ by P as 1.	At. Wgts.
C	63·369	5.2807	34·9	420
H	10·491	10·4910	69·3 + 2	72
P	4·691	0·1512	1·0	31
O	21·449	1·3405	8·8	144
	100·000			667

The atomic weight derived from the Pb pyrophosphate is 663, which closely approximates the quantity found directly.

Summary

The conclusion drawn from this experience was, that chemolysis, with an amount of alkali insufficient to satisfy at least three molecules of acid, developed from one molecule of kephaline, must stop short of complete decomposition, and produce intermediate products, of which the principal one is kephalophosphoric acid. It is probably an acid containing three acid nuclei:

$$\boxed{\left.\begin{matrix}\text{Kephalic}\\\text{Oxykephalic}\end{matrix}\right\}\text{Glycerophosphoric}} = \text{Kephalophosphoric.}$$

But no nitrogenised nucleus, and by further chemolysis may split up into the acids obtained by its side.

Acids in alcohol solution.

b. *The Alcoholic Solution*, from which kephalophosphate has been precipitated by lead acetate, was distilled to about 300 c.c. This liquor, on cooling and standing, deposited an oil, which was isolated, and found to float on water, but on boiling it became *viscous and solid in the hot*, and the water became white, as if the acid were emulged in it. There is, therefore, here no oleic or other fusible fatty acid, but one or several new acids, which had not combined with lead in the acid solution, as no alkali had been employed to neutralise the acids before the addition of the first lead acetate. Oil and liquid were treated with ammonia to strong alkalinity, whereby a white emulsive solution was produced. To this water and watery acetate of lead were added, until, and as long as, a precipitate was produced. This was white, adhesive, and bulky. It was filtered, washed, and dried, powdered, dissolved in ether, filtered, decomposed with hydrochloric acid and water, the ether solution was washed, filtered, and when clear distilled to small bulk.

Lead salt produced.

Transformed into baryta salt.

The red solution was treated with watery ammonia, filtered, baryum chloride added, when a bulky precipitate was obtained. This was washed for a long time, until washings were nearly free from baryta, the precipitate was dried in air, and treated with ether; a coloured salt dissolved, and a white salt remained undissolved.

a. Coloured salt, soluble in ether = Oxykephalate of baryum.

Two salts separated by ether. Baryum, oxykephalate, &c.

The oxykephalate of baryum dissolves rapidly and abundantly in ether, and is precipitated from this solution by absolute alcohol. It is always of a dark colour, which intensifies in the ether, probably by oxydation. The salt is insoluble, or but little soluble, in boiling alcohol, and is not deposited from this solution in crystals as oleate of baryum is. The name of the acid is taken from the fact that while similar in composition to kephalic acid, it contains more oxygen than that acid. It cannot be decolorised by animal charcoal, either when in the state of sodium salt, or when in the free state dissolved in boiling alcohol, and all operations seem only to assist in furthering its oxydation. It seems that its radical, while in the kephaline, is the principal cause of the assumption of colour and fluorescence by that principle.

β. White salt, insoluble in ether = Kephalate of baryum.

Properties of free acid.

The kephalate of baryum appears very much swelled in ether; when dry it is white and pulverulent. Hydrochloric acid and water extract the baryum, and washing with water leaves the acid soluble in ether; the ether distilled off leaves the acid as a coloured soft mass, which fuses at 26°, congeals at 25°, and crystallises in rosettes like margaric acid. It dissolves easily in absolute alcohol, forming colourless fluid; a few drops of water added to alcohol cause acid to separate as an oil on top of spirit; on standing, rosettes of crystals, colourless, form in this oil, and may be separated. The spirit deposits white clouds of the acid.

Differences from oleic acid

This acid differs from oleic by its baryum salt being entirely insoluble in boiling alcohol. It is not fluid at ordinary temperatures, but semi-solid, and fuses only at 26°, and from concentrated spirit it is entirely separated and crystallises, while oleic acid remains dissolved in such spirit, and does not crystallise at such temperatures.

In the manipulation of these acids in the presence of absolute alcohol the formation of ethylic ethers, which easily ensues, has to be carefully avoided.

3. *The Acid insoluble in Alcohol.*—On exposure to the air it assumed a very dark colour, apparently from attraction of oxygen or moisture. The whole easily dissolved in ether; the solution had a dark red colour, and exhibited a powerful green fluorescence. Addition of two or three volumes of absolute alcohol produced a slight opalescence, but no precipitate, which seems to exclude kephaline. This was further confirmed by the fact that lead acetate produced no precipitate in the mixture, consequently the lead salt, if any be formed, is soluble in ether, as well as ether alcohol, in which latter lead-kephaline is insoluble.

The whole of the acid was dissolved in ether, neutralised with ammonia, $Ba\ Cl_2$ added, and the mixture shaken; it was washed with water, filtered from a small quantity of insoluble precipitate, and the solution mixed with an equal volume of alcohol. A baryum salt was precipitated, but imperfectly, and the precipitate was isolated and dried. It was small in quantity, much coloured, and was not analysed. It is probably an intermediate product of chemolysis.

Acid filtrate.

4. *The Acid Filtrate* containing that phosphorus which was not combined with the kephalophosphoric acid, in the form of glycero-phosphoric acid; some nitrogen in an unknown form; the sodium chloride

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Lead glycerophosphate.

Calcic glycerophosphate.

together with some free hydrochloric acid, was evaporated to a low bulk and its acidity carefully neutralised by caustic soda. Acetate of lead was now added as long as a precipitate was produced, and the white deposit was filtered off. It was boiled, filtered, and washed with hot water, decomposed with $H_2 S$, the filtrate neutralised with calcic carbonate and lime water, filtered and evaporated. When concentrated the solution deposited crystalline *calcium glycerophosphate.*

5. The solution from which glycerophosphoric acid had thus been removed was freed from lead by $H_2 S$, the acetate was decomposed by repeated addition of hydrochloric acid, and evaporation to dryness, and the crystalline magma was treated with absolute alcohol to extract the hydrochlorate of the expected nitrogenised body. To this alcoholic solution $Pt\,Cl_4$ was added, when a slight yellow precipitate ensued, which was separated by filtration, washed with alcohol, dried. It could only represent a small portion of the nitrogen contained in the chemolysed kephaline; as the volatilised vapours had not been collected some volatile alkali may have escaped unnoticed. The *alcoholic mother liquor* of this platinum precipitate, was freed from platinum by $H_2 S$.

Oily Pt Cl4 salt.

Evaporated, it left a syrupy residue, this was again treated with little alcohol and $Pt\,Cl_4$ and a slight deposit removed. The liquor on addition of much ether deposited an *oily body,* soluble in absolute alcohol re-precipitated by ether. Distilled with dilute $H_2 S O_4$ and $Mn O_2$, it gave a distillate which smelled of *acetic acid,* and after neutralisation by soda, was reduced by $Ag\,N\,O_3$ and by $Hg\,N\,O_3$, consequently contained *formic acid.* These may be considered as decomposition products of *glycerine,* or of a body *containing its radical.*

Summary of Results of first Chemolysis of Kephaline.—All first products are soluble, the soaps imperfectly, in water. Hydrochloric acid precipitates a mixture of four fatty acids.

Summary.

1. Kephalophosphoric acid, consisting probably of kephalic, oxykephalic, and glycerophosphoric acid, yet in combination, therefore imperfectly chemolysed.
2. Kephalic acid.
3. Oxykephalic acid.
4. Acid insoluble in alcohol (small quantity).
5. Glycerophosphoric acid.
6. Ammonia.
7. Glycerine.
8. A base giving oily $Pt\,Cl_4$ salt, and being perhaps glyceramine of a new type. It is most difficult to deal with, as its solubility in water, alcohol, as hydrochlorate and as $Pt\,Cl_4$ salt is very great, and its precipitation by ether by no means complete.

Second chemolysis.

Water bath.

Sand bath.

Chemolysis of Kephaline, second Experiment by Soda.—40·7 grms. of pure kephaline, purified by the water solution, filtration and H Cl process as before described, were mixed with 5 grms. of crystalline soda hydrate dissolved in 2 litres of water. The same phenomenon was observed during the boiling as in the first experiment. The boiling was continued during about 18 hours, of which 3 hours took place in water bath, and the other 15 hours on sand bath, the time taken to heat it to boiling on the three days during which experiment lasted not included. While on the first and second day the mixture had set into a jelly, it did after the last boiling not become gelatinous again, but remained a somewhat turbid thick fluid. To this H Cl was added until the precipitate was curdy and the fluid strongly acid. The precipitate was separated by the filter. It could be washed but imperfectly, as after consolidation on the filter, the precipitate set into a gelatinous tremulous

H Cl.

Filtration.

Solution of acids in N H4 H O.

solid mass, which allowed no washing water to pass. This mass of acids was placed into a wide-mouthed bottle, shaken with water and treated with caustic ammonia. It formed a complete solution, which was filtered on hot funnel and left no trace of residue. The solution was opaque, and on agitation showed the silky clouds common to soaps. To this solution acetate of lead was added until the precipitate was curdy, and the liquid distinct and filterable. It was now passed through french filtering paper, and the precipitate washed with much water, being agitated constantly with a glass rod, so that all parts were well penetrated by water. When the filtrate was free from chlorine and from lead (from excess of acetate), the precipitate was allowed to drain on paper and a cloth and dried. It took many days to dry, being frequently crushed and stirred.

Acetate of lead precipitate.

Filtration and washing.

Ether extracted a colored body, and left a white salt insoluble. This was separated by filtration, and washed by being twice removed from filter, and shaken in a bottle with ether. Filtration was always difficult owing to the finely divided state of the salt.

Ether extraction.

The white Pb salt insoluble in ether was dried in the vacuum, and yielded, on preliminary analysis, results which showed it to be impure.

White salt insoluble in ether.

It was further transformed into baryum salt by H Cl, water, and ether, solution of acid in NH_4HO, and precipitation by $BaCl_2$. The salt was extracted by boiling alcohol, and what remained insoluble was reserved for analysis.

The coloured Pb Salt soluble in Ether was red in transmitted light, and fluoresced green, altogether appeared like a solution of kephaline. It was concentrated by distillation, and the solution precipitated by absolute alcohol; a viscous salt fell down, which became hard in alcohol, was drained and dried in vacuo. After preliminary testing, it was transformed into Ba salt by H Cl, water and ether; solution of acid in NH_4HO and precipitation with $BaCl_2$; solution in ether and precipitation by alcohol.

Salt soluble in ether.

These salts, therefore, correspond to the *kephalate* and *oxykephalate* of the first chemolysis. Their further study is reserved for future opportunities.

Transformed into baryum salt.

Treatment of the Filtrate containing Glycerophosphoric Acid and Ammonium Base.—It was neutralised with baryta water, the excess of reaction being allowed towards alkalinity. A pure saturated solution of *lead chloride* in water was now added, which produced a flocculent white precipitate of glycerophosphate. The advantages of the lead chloride were, that no new acid was introduced into the fluid, from which the ammonium base had yet to be extracted. The fluid became slightly acid, and was corrected by baryta water cautiously added. When all was precipitated the *glycerophosphate of lead* was filtered off, washed, and dried. The mother liquor was concentrated, and then gave another not inconsiderable precipitate with lead chloride solution. The reaction was continued until a filtered sample of liquid remained clear with the chloride, and the second precipitate was isolated and united with the primary one. The previously feebly alkaline liquid was now feebly acid; it was evaporated to a low bulk and then to dryness. It was now dissolved in a minimum of water, and precipitated with absolute alcohol, until this reagent produced no further turbidity and no deposit on standing 12 hours. The alcoholic extracts were united, concentrated, and precipitated with $PtCl_4$. A yellow precipitate fell, which will be described further on. The matter insoluble in alcohol ($NaCl$, $BaCl_2$, and some undefined organic matter), re-dissolved in water, and again treated with $PbCl_2$ solution gave a third precipitate of glycerophosphate, which was added to the other quantities. This

Baryta water added.

Lead chloride added.

Glycerophosphate removed as lead salt.

Liquid evaporated and extracted with alcohol.

$PtCl^4$ precipitate.

Third precipitate of Pb glycerophosphate.

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process shows how difficult it is to remove completely glycerophosphoric acid from these solutions. They require repeated concentration and neutralisation, and whatever the lead salt employed the supposed insolubility of the glycerophosphate of lead is not sufficiently great in these fluids to cause the whole of it to fall down.

The glycerophosphate of lead dried to a hard slightly colored mass. (This hardening of glycerophosphates is also observed upon baryum salt, and the condition must be borne in mind when it is subsequently intended to decompose these salts.) It was repeatedly crushed, ultimately powdered and dried in water oven. The total weighed 7·4435 grm. Now assuming the 40·7 gms. kephaline to have contained (at 4·2°/₀ P) 1·7 grm. phosphorus, then this corresponds to 19·38 grms. glycerophosphate of lead, of which theory is:—

Acid.		Pb salt.	Pb pyrophosphate.
3 C	36	36	—
9 H	9	7	—
P	31	31	2 P 62
6 O	96	96	7 O 112
	172	Pb 207	2 Pb 414
		377	588

But as only 7·4435 grms. were obtained there is a deficiency of 11·9365 grms.

Preliminary analysis.

In order to ascertain approximately the purity of the lead glycerophosphate, 0·9110 grm. was burned until white, and left 0·7440 grm. $Pb_2 P_2 O_7$ while theory required 0·7104. The white residue was treated with acetic acid and found insoluble in it, which corresponds with pyrophosphate.

Transformed into calcium salt.

The lead salt was now decomposed with hydrothion, the filtrate treated with $C O_2$ in the cold to expel $H_2 S$, and then with milk of lime to alkalinity, filtered and treated with some $C O_2$. The filtrate after 12 hours standing was evaporated near the boiling point, and filtered hot from the white precipitate of calcic glycerophosphate. This when dry weighed only 0·727 grm. Of this 0·3400, after strong ignition with HNO_3, left 0·207 grm. residue, equal to 60·8 °/ $Ca_2 P_2 O_7$. Pure glycerophosphate should leave 60·5°/₀ of pyrophosphate.

Acid Glycerophosphate of Calcium.—The aqueous filtrate from which the above salt had been removed whilst hot, was mixed with three volumes of alcohol, when a light bulky precipitate ensued. This was isolated by filtration, washed with alcohol and dried. It weighed 0·526 grm. Of this 0·2446 grm. gave 0·1250 grm. pyrophosphate, equal to 51·1 °/₀ residue. This corresponds to a salt which might be obtained from acid glycerophosphate of calcium by combustion.

$$\begin{array}{l} C_3 H_7 \ Ca P \ O_6 \\ C_3 H_9 \quad\ \ P \ O_6 \\ \hline C_6 H_{16} Ca P_2 O_{12} = \text{acid glycerophosphate of calcium.} \end{array}$$

This on combustion may lose—

$$\begin{array}{l} C_6 H_{14} \qquad O_5, \text{ and leave} \\ \hline \end{array}$$

$H_2 \ Ca P_2 O_7$, or half saturated acid pyrophosphate of calcium, or a body isomeric with it. By this theory 51·4 °/₀ residue should be left, which differs but little from 51·1 °/₀ found.

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The quantity of glycerophosphoric acid lost in the process of transformation is enormous, and this is invariably observed in all experiments which I have made. This experience, and that of the hardening of the lead salt from brain matters, which is not observed upon synthetically prepared lead salt, and the peculiar hardening and fusion of the baryta salt from brain, which reminds of the bearing of kryptophanates and paraphanates from urine, and kreatylates from flesh, call for a renewed study of this acid.

Platinic chloride precipitate.

The Platinic Chloride Precipitate.—The yellow precipitate was washed with absolute alcohol. On drying it became horny, crumbled up, was viscous outside and discoloured, and adhered strongly to the paper. Water restored yellow colour and pulverulence. It dissolved in hot water, of which much was required. On cooling brilliant small crystals were deposited, amounting to 0·9428 grm. This by analysis proved to be almost pure ammonium salt, containing only a trace of potassium, which raised the residue left on combustion to 45·56 %, while 44·36 % are required by pure NH_4 salt. By evaporation over H_2SO_4 two further small crops of ammonium salt were obtained; the rest of the solution dried up to a thick liquid *and did not crystallise.*

The filtrate from the $PtCl_4$ salt was mixed with a large excess of ether until this produced no further turbidity. An *oily matter* settled, which was purified by repeated solution in alcohol and precipitation by ether. It was not analysed, as there were no guarantees of its freedom from free glycerine. It was distilled with H_2SO_4 and MnO_2, and yielded an acid distillate, in which, after neutralisation with soda, the presence of *formic acid* was signalised by the usual tests.

This platinum salt which from the reactions detailed may split up into glycerine and ammonia, reduces the platinum rapidly when left in contact with ether alcohol, and becomes black. Altogether this product is one of the most difficult matters to treat, and particularly as it is only obtained in small quantities.

Third Chemolysis of Kephaline, with Baryta Hydrate.—The kephaline was prepared by the HCl process and well washed with water. The quantity used was 27·8 grms. It was placed in a flask connected with a condenser, and a solution containing 80 grms. BaH_2O_2, $10H_2O$ was added. The mixture was boiled during five hours on a sand bath, when the precipitate became adhesive and flask cracked. After cooling and filtering the residue was twice boiled with water, during which it became quite soft and semifluid; it was again thrown on a filter and washed to neutrality. The washings were united with first filtrate.

The baryum salts.

The baryum salts being drained of water were rubbed in a mortar with ether, and then shaken in a bottle with much ether. The ether *dissolved a colored salt*, leaving a *white salt undissolved*, from which solution was separated by filtration.

The insoluble white salt was dried in air; later in vacuo. It had the appearance of kephalate, and was reserved for future analysis.

The soluble colored salt had the appearance of oxykephalate, was red and fluoresced green. Solution was concentrated and precipitated by absolute alcohol. The precipitate was dried in vacuo and reserved for future analysis.

Baryum glycerophosphate.

The liquid containing the glycerophosphate and expected ammonium base was treated with carbonic acid until no more precipitate was produced, filtered, and filtrate concentrated on a water bath nearly to dryness. During this evaporation it did not deposit any salt, as does lime salt. The viscous mass was diluted with a little water to fluidity, placed in a bottle, and mixed with absolute alcohol until no further precipi-

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tate was produced. The precipitate was filtered off and washed with alcohol.

The precipitate consisted of baryum glycerophosphate. It was bulky, white, and granular, probably alcoholate-hydrate. On standing, it contracted, and became horny, transparent, and partly fused. Placed in a glass dish, it fused entirely in a few days, and then dried to a brittle mass.

Summary of Analyses.

C	12·611
H	2·933
Ba	40·950
P	9·266
O	34·240
	100·000

Formula.—$C_3 H_7 Ba P O_6, H_2 O$.

Alcoholic solution.

The alcoholic solution from which the glycerophosphate had been removed was distilled to near dryness, and placed in a vacuum to crystallise. A few rosettes of crystals formed, the rest remained syrupy and alkaline. The crystals were white rhombic, spear-shaped, under microscope. In sublimation tube, they blackened, did not sublimate at all, fused, gave only stinking distillates, which were heavy, and did not crystallise at all (against sarkosine and alanine). The solution in water has a slightly acid reaction, so they are not solutions of an alkaloid or an ammonium base. Quantity too small for further study.

Last mother liquor.

The mother liquor, evaporated to a syrup, gave a few secondary crystals, too minute for isolation. The strongly alkaline syrup was soluble in water, less in alcohol, insoluble in ether. $H_2 S O_4$, $H N O_3$, and $H Cl$ acids gave no precipitates in it. Acetate of lead gave a strong precipitate. $Hg Cl_2$, cold saturated solution, gave a strong precipitate. Phospho-molybdic acid gave a slight precipitate. $Pt Cl_4$ and a little $H Cl$ gave a strong precipitate, which became adhesive and fused in air. Ether gave a strong precipitate in absolute alcohol solution. This was isolated, dissolved in absolute alcohol by the aid of heat, when a portion became insoluble, filtered and precipitated by much ether. Red fluid, oily body, becomes crystalline, on standing, in parts, reduced and brown in others. When isolated, is not entirely soluble in alcohol, therefore changes without intermission.

Kephaline and Lead.—The following preparation was made from a specimen which had not undergone the purifying process with water, filtration, and hydrochloric acid. It may, therefore, have contained some of the kephaline as ammonium salt. It had been thrice precipitated from ether by alcohol, and when last dissolved in ether, had stood during 24 hours in ice, to deposit the last traces of cerebrine.

Analyses (1.) 0·4622 grm., dried in vacuo, and ultimately at 90° to 92° until constant, gave 1·0086 grm. $C O_2 = 0·27507$ grm. C, or 59·51 % carbon, and 0·3877 grm. $H_2 O = 0·04307$ grm., or 9·31% hydrogen.

(2.) 0·3748 grm. gave 9·1c.c. N at 17·5° C., and 766 m.m. B., which, with corrections for potash column of 216 m.m. of 1·3 sp. gr., and other corrections, leads to 2·7 % nitrogen.

(3.) 0·6125 grm. fused with soda, nitre, and carbonate, &c., gave phosphate of magnesium = to 0·0223 P, or 3·64 % phosphorus.

Summary of Analysis of Free Kephaline—

		÷ by At. Wgts.	P as 1.	P=3.
C	59·51	4· 96	42	127
H	9·31	9· 31	79	238
N	2·73	0·195	1·6	4·98
P	3·64	0·117	1	3
O	24·81	1·550	13	39·7
	100·00			

Hypothesis regarding excess of nitrogen.

It will thus be seen that all the elements are in proportions required by pure kephaline, except the nitrogen, which is six tenths of an atom too high, or amounts to nearly five atoms, if three atoms of phosphorus are assumed. I do not admit any analytical fault, where it cannot be proved, simply because the results are anomalous. They must, therefore, be dealt with as such, and explained on the basis of the facts. Now, if as above surmised, any ammonia had been contained in the salt, two-thirds of the kephaline must have been so combined. Or if, as is probable from analogy with myeline, there are kephalines containing amidated acids, as proximate conjugated compounds, which amidated acids have also now and then been found in the chemolyses of kephaline, then it might be supposed that out of six fatty acid radicles in two molecules of kephaline, two fatty acid radicles were amidated, a condition represented by the following diagram, in which R signifies radical and the apposed letter P "containing phosphorus," and N "containing nitrogen"—

R P	R N	R N
	R	
R P	R	R N
	R	
R P	R	R N
	R N	

But the question is less foreclosed if the facts are expressed by the formula—

$$\left.\begin{array}{l} C_{42}\,H_{80}\,N_2\,P\,O_{13} \\ C_{42}\,H_{79}\,N\;\;P\,O_{13} \\ C_{42}\,H_{80}\,N_2\,P\,O_{13} \end{array}\right\} = C_{126}\,H_{239}\,N_5\,P_3\,O_{39}$$

No sulphur. Made into lead salt.

The preparation was proved to be free from sulphur by special analysis. Some anomalies in details evidently do not yield to either hypothesis. The specimen of kephaline was therefore again frozen in ether, and deposited a vestige of white matter; the clear solution was then poured into absolute alcohol containing lead acetate; the precipitate was filtered, washed, suspended in absolute alcohol, warmed to 45° to 50°, filtered hot, to extract possible traces of cerebrine and soluble matters. No deposit occurred in this alcohol on cooling. The lead salt was dried in vacuo, powdered, and found highly electric; it was suspended in and extracted with ether.

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Analyses (1.) 0·4817 grm. gave 0·7797 grm. CO_2, equal to 44·144 % C; and 0·2854 grm. H_2O, equal to 6·583% H.

(2.) 0·4326 grm. gave 4·25c.c. equal to 3·73 c.c. normal = to 1·07 % N.

(3.) The Pb and P were determined by fusing a portion of salt in soda and nitre mixture, dissolving in HNO_3, and determining lead as sulphide, and phosphorus as $Mg_2P_2O_7$.

0·9682 grm. dried at 100° gave 0·3115 grm. Pb S equal to 27·86 % Pb.

The filtrate from Pb S yielded 0·1030 $Mg_2P_2O_7$, equal to 2·97 % P.

(4.) 0·8013 grm. gave 0·2544 grm. Pb S, equal to 27·49 % Pb. This, tested with HNO_3 and H_2SO_4 and ignited, left 0·3062 grm. $PbSO_4$ = to 26·10 % Pb. The filtrate from Pb S yielded 0·09 $Mg_2P_2O_7$ = to 3·09 % P.

(5.) A third Pb determination by burning with H_2SO_4, and extracting phosphoric acid, gave 26·54 % Pb.

Summary of Analyses—

C	44·14				
H	6·583				
N	1·07				
Pb	27·86	27·49	26·10	26·54	Mean = 26·99
P	2·97	3·09			Mean = 3·03
O	18·25				
	100·00				

Computation of results.

Calculation shows that in this compound the lead does not stand in any stœchiometric relations to any one element. It is in excess by about one-fourth over the quantity it should be if one atom of kephaline were combined with one atom of lead. Deducting the lead, and calculating the organic matter, *i.e.*, 73·01 as 100 we get—

	$\bar{K}$ in Pb salt.	Free $\bar{K}$ before.	Pure $\bar{K}$ gives.	Theory requires.
C	60·5	59·51	60·00	60·28
H	9·1	9·31	9·39	9·44
N	1·46	2·73	1·68	1·67
P	4·06	3·64	4·27	3·70
O	25·02	24·81	24·66	24·88
	100·00	100·00		

The ether and lead treatment, the combination and purification thereby effected has therefore brought this kephaline much nearer to the composition of the purest. The nitrogen has fallen below the per-centage required, the phosphorus has risen a little. There if, therefore, advantage in combining kephaline with lead, with a view so again decomposing it, and thus purify the substance. But the advantage is probably less than that obtained by the water and hydrochloric acid treatment. Moreover, the treatment is expensive in substance and ether, and the compound is not in atomic proportions, but tends to be basic. We shall, lower down, meet with a compound of oxykephaline with lead, which actually seems to be a tetrabasic fully saturated compound. Probably, further experiments on the combination of kephaline with lead may teach the conditions under which it

will combine with this element in atomic proportions. It has this advantage over other bases, that it is less soluble in water, and therefore not liable to be deranged by moisture after being once combined with kephaline.

Oxykephaline with cadmic chloride, $C_{42} H_{79} N P O_{14}, Cd Cl_2$.—When the white matter (Ox) has been extracted with ether and the kephaline removed from the ether solution by precipitation with absolute alcohol, there remains a bulky solution containing all lecithine (?), much myeline and some kephaline, together with the cholesterine previously contained in the white matter. When to this solution $Cd Cl_2$ is added a voluminous precipitate ensues, which, after washing, yields to ether a quantity of coloured salt. This after concentration is precipitated by alcohol, and purified by repetition of this treatment. It was of interest to know the composition of this precipitate. (The composition of the insoluble precipitate is given under myeline and lecithine.)

Analyses—(1) 0·4547 grm. dried at 80° gave 0·8025 grm. $C O_2$, equal to 48·12 °/$_0$ C, and 0·309 grm. $H_2 O$=to 7·55 °/$_0$ H.

(2) 0·5356 grm. gave 7c.c. N at 22° C. and 764 m.m. B. KHO column =22·4 m.m. Hg; equal to 6·15c.c. N normal, or 1·43 °/$_0$ N.

(3) 0·9042 grm. fused with soda, nitre, and carbonate gave 0·2708 grm. Ag Cl equal to 7·40 °/$_0$ Cl (these require to form $Cd Cl_2$ 11·66 Cd); and 0·1102 Cd O=11·65 °/$_0$ Cd; and further 0·1142 $Mg_2 P_2 O_7$ equal to 3·524 °/$_0$ P.

Per cents. found.			÷ by At. Wts.	÷ Cd. as 1.	In 100 of organic matter.
C	48·12	81·95	4·01	42·21	58·71
H	7·55		7·55	79·47	9·21
N	1·43		0·102	1·07	1·74
P	3·524		0·113	1·18	4·30
O	21·33		1·33	14·00	26·02
Cd	10·65	18·05	0·095	1.00	99·98
Cl	7·40		0·208	2·18	
	100·004	100·00			

leading to formula $C_{42} H_{79} N P O_{14}, Cd Cl_2$.

This compound is noteworthy on account of two features, viz.: that it coincides with the composition of the theoretical $Cd Cl_2$ salt of kephaline, plus one atom of oxygen, and that the $Cd Cl_2$ is a complete molecule, combined with an apparently complete molecule of organic matter. Such compounds as this and the ones to be described hereafter with 15 atoms of oxygen, make one regret that there are no means of determining oxygen directly in organic chemistry. The oxygen is estimated by the void left by the substances determined, and this gives an opportunity for small impurities to be summed up under the guise of this element. Now the substance here considered had not undergone the process of purification by water, filtration, and acid, and it may therefore have been kephaline to which some slight impurity was attached. On the other hand there is no proof of the existence of such impurity and none could be found by testing. It is therefore necessary to consider this substance as a genuine compound of a kephaline containing an atom of O more than the normal kephaline, to which it will be convenient to apply the term *oxykephaline*. In any

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case the isolation of this body from the mother liquor of kephaline by the ether process, by means of $Cd\,Cl_2$ is of sufficient importance in itself, no matter how the question of the atom of oxygen may ultimately be decided by further research.

Behaviour of a similar salt with water.

Behaviour of a similar Salt with Water.—A portion of a salt similarly obtained, though not analysed, was digested with water, whereupon it began to swell, and the water after filtration was found to contain large quantities of $Cd\,Cl_2$, proved expressly by the hydrothion and silver tests. When the extraction with water had been continued for some time filtration was effected, when during washing, the body swelled to such an extent as to clog the filter. There was therefore no guarantee of its purity from $Cd\,Cl_2$, except that it began to dissolve in water. The experiment proves that by simple digestion with water much $Cd\,Cl_2$ is extracted, but probably the entire amount can only be removed by a long *process of dialysis.* The results of experiments bearing in that direction will be described on a future occasion. Here it may be stated that the kephaline compounds are dialysed without a diaphragm, their own substance acting as dialysor in contact with water; the diaphragm is only wanted to keep them from dissolving. The compound cannot be freed from cadmium by $H_2\,S$, as when so treated in ether solution, it only assumes a yellow colour, and the $Cd\,S$ remains dissolved. This peculiar bearing of many phosphorised compounds will also be fully described lower down. These, in themselves, highly remarkable peculiarities, throw many difficulties into the way of the extraction of the organic matter from the $Cd\,Cl_2$ precipitates, which are on the other hand so convenient for the removal of the organic matter from a highly complex mixture.

Dialysis necessary.

Peroxykephaline $C_{42}\,H_{79}\,N\,P\,O_{15}$.

How obtained.

A quantity of kephaline, which is described in my notes as having been obtained after frosting the ether solution and precipitating it by absolute alcohol, was subjected to elementary analysis, without having undergone the water filtration and HCl process.

Analyses.

Analyses.—(1) 0·4206 grm. dried at 80° C gave 0·8906 grm. $C\,O_2$ equal to 57·750 °/₀ C; and 0·3370 grm. $H_2\,O$ equal to 8·902 °/₀ H.

(2) 0·6160 grm. gave 8·9c.c. gas at 761 m.m. and 25 m.m. Hg potash column, equal to 7·75c.c. normal or 1·573 °/₀ N.

(3) 0·8190 grm. fused with caustic soda mixture, &c. gave 0·1080 $Mg_2\,P_2\,O_7$, equal to 3·68 °/₀ P.

Summary—

	In 100	÷ by At. Wts.	÷ by N = 1.
C	57·750	4·8125	42·85
H	8·902	8·9020	79·26
N	1·573	0·1123	1·00
P	3·680	0·1187	1·05
O	28·095	1·7560	15·63

Formula.

Leading to formula $C_{42}\,H_{79}\,N\,P\,O_{15}$; At. W. = 868.

Transformed into lead salt.

Transformation of this Body into lead Salt.—About 10 grms. of the analysed substance were dissolved in ether, and to this solution *a warm solution of alcoholic lead acetate* was added. A viscous precipitate was produced, which settled in a mass. The lead acetate was not used in excess, the addition being discontinued while there was still a little matter in solution admitting of precipitation. The mother liquor was poured off, the mass of the precipitate was stirred and rinsed with a little ether first, and afterwards with absolute alcohol. The precipitate

Insoluble part.

was now digested with a quantity of ether, which dissolved much and left a portion undissolved. The insoluble part had a more gelatinous appearance than the original whole, and was disregarded. The solution was filtered off and precipitated by absolute alcohol, the precipitate was washed four or five times with absolute alcohol, dried and analysed.

Analyses.

Analyses of the Salt soluble in Ether.—(1) 0·830 grm. dried at 80° C, were fused with soda, nitre, and carbonate mixture, the lead precipitated by H_2S, and the PbS transformed into $PbSO_4$ by ignition with HNO_3 and H_2SO_4. The $PbSO_4$ weighed 0·3872 grm. equal to 31·86 °/₀ lead. The portion of salt further gave 0·0808 grm. $Mg_2P_2O_7$ equal to 2·71 °/₀ P.

(2) 0·4255 grm. gave 0·5986 grm. CO_2, equal to 38·367 °/₀ C; and 0·2206 grm H_2O, equal to 5·760 °/₀ H.

(3) 0·5653 grm. gave 5·1c.c. N at 25° C and 764 m.m. B. KHO column = 22 m.m. Hg, equal to 4·41c.c. N normal or 0·9755 °/₀ N.

Summary—

	°/₀ found	$C_{42}H_{75}Pb_2NPO_{15}$ requires
C	38·367	39·436
H	5·760	5·868
N	0·9755	1·095
P	2·717	2·425
O	20·312	18·782
Pb	31·869	32·394
	100·000	100·000

It will be seen by a comparison of the oxygen quantities in the free body, with those of the salt, that there is no reason for assuming lead to be present as oxyde; on the contrary, the H being less in the organic part of the lead salt than in the free body justifies the assumption of a substitution of H_4 by Pb_2.

Comparison of the Organic Matter in the Lead Salt, with the Composition of the Free Body and of the Organic Matter in a Salt of Kephaloïdine with Cd Cl₂.

Comparison of results.

	°/₀ found in original free peroxykephaline.	°/₀ found in Cd Cl₂ salt of kephaloidine.	°/₀ found in lead salt of peroxykephaline.
C	57·75	57·91	56·31
H	8·90	8·82	8·30
N	1·57	1·67	1·43
P	3·68	3·71	3·98
O	28·09	27·78	29·81

The phosphorus, as in nearly all analyses, is found somewhat too high, rising in the lead salt to 5 as compared with N as 4. But on the whole, the change by the removal of some insoluble salt is not so great as to negative the assumption that the free body, and body contained in the lead salt have essentially the same composition, more particularly *the proportion of oxygen has not been decreased by the combination.*

Kephaloidine.

The substance thus designated is much like kephaline as above described, but presents some slight differences, which, though it may be

Why distinguished from

identical *in composition* with kephaline, imply the necessity of a preliminary distinction. It is obtained from buttery matter; kephaline from white matter; it is more fluid than kephaline when first precipitated, and never dries to the same hard brittle substance as kephaline, but presents a fused appearance. It presents the same irregularities in its combinations as kephaline; *it forms oxykephaloidine*, which like oxykephaline combines with a molecule of $Cd\,Cl_2$ forming a pretty concise salt.

Solubility in water and filtration.

Solubility in Water and Filtration.—Five grams of dry, hard, but viscous kephaloidine were dissolved in 500 c.c. of cold water with trituration. The substance became mucous at first, and on agitation in a long cylinder was disintegrated, and a turbid emulsion-like solution resulted. This was passed through the pressure filter, and passed easily 10 layers of English filtering paper. Next 10 layers of Swedish paper were employed, when an entire atmosphere of pressure allowed the liquid to pass but slowly.

Dialysis.

Bearing of Kephaloidine in Dialysing Apparatus.

First experiment.

First Experiment.—The foregoing solution after filtration, and subsequent treatment with animal charcoal, which did not make it clear, was distributed over two dialysers of parchment paper in gutta percha rings, the one six, the other five inches in diameter, and placed over 200 and 300 c.c. of water respectively. After 24 hours, the water gave but slight evidence of containing kephaloidine, by giving a mere vestige of precipitate with lead salt, while the original solution gave a very copious precipitate. Only a very minute portion of matter therefore had passed the diaphragm.

Second experiment.

Second Experiment.—A solution and emulsion of about 20 grms. of kephaloidine in 500 c.c. of water was, without having been filtered, subjected to dialysis, on three diaphragms. Each diaphragm after 24 hours had passed some kephaloidine, but only a very small quantity, as shown by the lead precipitate. The original solution on the dialyser gave a copious thick precipitate with the same lead salt. It was thus shown that a one per cent. solution can hardly be dialysed, while a four per cent. solution dialyses a little, but not enough for practical purposes. It may rather be expected that kephaline and kephaloidine act in watery solution, like colloids, and remain on dyalyser, while allowing the crystalloids mixed or combined with them to pass into the pure water. I have shown that they act as dialysors themselves when placed into pure water, and yield up the soluble salts or bases or acids with which they are combined. Probably dialysis by parchment paper may be found effective in completing this process.

May act like the colloids.

Bearing of the Ether Solution of Kephaloidine with Water.

Ether solution and water.

The kephaloidine was twice precipitated by alcohol from ether solution, and then redissolved in ether. A few drops falling in water are precipitated, and on shaking, a turbid emulsion is formed. Boiling transforms this into a turbid mucous mass with thick and viscid flakes. Hydrochloric acid added to this emulsion causes white curdling, and the white flakes can with difficulty be filtered off. The filtrate is white and turbid.

Water, hydrochloric acid, and ether in certain proportions produce a thick white jelly; a little more ether separates oily ether solution, which gives no precipitate with alcohol, or in this mixture with $Cd\,Cl_2$ and contains therefore $H\,Cl$.

Ether solution mixed with little water becomes a *solid white mass;* more water produces curds, ultimately emulsion and solution. A jelly thus produced with ether and much water deposited the ether solution on the surface. This with benzole, gave a white dense precipitate, re-soluble in ether and again precipitated by benzole.

Ether solution and little water.

Kephaloidine is easily soluble in benzole; treated with H Cl gas, this solution changes colour, but gives no precipitate; alcohol added to this gives a little precipitate, soluble in excess; ether gives no precipitate in the benzole H Cl solution. A solution of kephaloidine in anhydrous ether is not precipitated by benzole; the white dense precipitate described above requires the presence at the same time of water, HCl, ether, benzole, and kephaloidine. It seems to be a voluminous and stiff emulsion, which lies for days on blotting paper like jelly and ultimately dries to a thin film of kephaloidine.

Kephaloidine in benzole.

Reactions of the Watery Solution of Kephaloidine.

Hydrochloric acid produces a dense slightly yellow precipitate, which, after isolation, is soluble in ether and not precipitated by alcohol. In the filtrate from this precipitate $Pt\,Cl_4$ produces the merest opacity. But in the ethereal solution of H Cl precipitate, alcoholic $Pt\,Cl_4$ produces a precipitate soluble in ether and re-precipitated by alcohol. H Cl.

Sulphuric acid produces a precipitate like that by H Cl. H_2SO_4.

Nitric acid, same as sulphuric. HNO_3.

Baryta water, Lime water, Cadmic chloride, Zinc chloride: All produce good precipitates which coalesce well on standing or agitation. $Ba\,H^2O^2$. $Ca\,H^2O^2$. $Cd\,Cl_2$. $Zn\,Cl_2$.

Mercuric nitrate gives a good curdled precipitate insoluble in $H\,N\,O_3$, but made slightly yellow thereby. $Hg\,N\,O_3$.

Baryum chloride also produces a good flaky precipitate. This body after isolation is insoluble in water and absolute alcohol, but readily soluble in ether. $Ba\,Cl_2$.

Platinic chloride gives a complete precipitate. $Pt\,Cl_4$.

Lead acetate gives a good precipitate. $Pb\,(C_2H_3O_2)^2$.

Mercuric acetate gives a very voluminous precipitate. $Hg\,(C_2H_3O_2)^2$.

Cupric acetate, a whitish flocculent precipitate. $Cu\,(C_2H^3O^2)^2$.

Kephaloidine Lead.—A specimen of kephaloidine which had been frozen in the ethereal solution, and precipitated by alcohol, was once more dissolved in ether, and placed in a freezing mixture for 24 hours. No deposit occurred. This ether solution also gave the reactions above described, and with silver nitrate its watery solution gave a copious white precipitate. The ether solution was poured slowly in a thin stream into absolute alcohol, when the kephaloidine was precipitated as a viscid mass. The whole of this was dissolved in water, and lead acetate added; a copious precipitate ensued which was filtered and washed, extracted with warm dilute alcohol, ultimately with warm absolute alcohol; it then *dissolved in ether without residue;* was precipitated by absolute alcohol, became pulverulent, was dried in vacuo and analysed.

Kephaloidine lead.

(1.) 0·9871 grm. dried at 70 to 75° C., later at 85° C., fused with caustic soda mixture, &c.; lead precipitated as Pb S and converted into $Pb\,S\,O_4$ gave 0·235 grm. $Pb\,S\,O_4$ equal to 16·26 °/o Pb, and 0·1296 $Mg_2P_2O_7$ equal to 3·666 °/o P. Analyses.

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(2.) 0·4579 grm. gave 0·8560 grm. CO_2 equal to 50·983 °/₀ C, and 0·3182 grm. H_2O, equal to 7·721 °/₀ H.

(3.) 0·6394 grm. dried at 100° c. gave 6 cc. N at 22° c. and 763 mm. B. KHO column = 21·4 mm. Hg; equal to 5·2 cc. normal, or 1·017 °/₀ N.

Summary.

	Summary.		In 100 organic matter.	Theory of $C_{42}H_{75}NPO_{13}$.
C	50·983	Total organic 83·740	60·88	60·28
H	7·721		9·22	9·44
N	1·017		1·21	1·67
P	3·666		4·37	3·70
O	20·353		24·32	24·885
Pb	16·260	16·260		
			100·00	100·000
	100·000	100·000		

It is at once evident that the Pb stands in no simple proportion to any other element. Kephaline lead if dibasic would require 19 °/₀, if monobasic 11 °/₀ of Pb. The molecule of the kephaloidinate contains thus rather more than half a molecule of Pb and is consequently a mixture of lead salt with free body. There is also an irrationality perceptible on the P which is too high, and the N which is too low. But on the whole the constitution, properties, and products coincide with those shown by kephaline of the compared formula.

Analyses.

Oxykephaloidine with cadmic chloride, 2 ($C_{42}H_{75}NPO_{14}$) + $CdCl_2$. In this case a quantity of kephaloidine obtained by the ether process, not purified by water, filtration, and HCl, &c., was transformed into $CdCl_2$ salt, and precipitated by alcohol; redissolved in ether, and the solution repeatedly frozen, and freed from some deposit, then precipitated by absolute alcohol. It could be dried at 80° C. without change.

Analyses.—(1.) 0·4694 grm. gave 0·9087 grm. CO_2, equal to 52·796°/₀ C, and 0·344 grm. H_2O, equal to 8·142°/₀ H.

(2.) 0·6396 grm. gave 8·75 c.c. N at 21·2° C. and 759 m.m. B; KHO column = 20·7 mm. Hg, equal to 7·69 c.c. normal, or 1·50°/₀ N.

(3.) 0·9368 grm., fused with caustic soda mixture, &c., gave 0·1340 grm. AgCl, equal to 3·53°/₀ Cl; filtrate neutralised with NH_4HO, and filtered from *slight* gelatinous precipitate, gave 0·1235 grm. $Mg_2P_2O_7$, equal to 3·68°/₀ P.

(4.) 0·9004 grm., fused as before, gave 0·1212 AgCl, equal to 3·33°/₀ Cl; further, 0·0430 grm. CdO, equal to 4·17 °/₀ Cd; the solution made alkaline, was not filtered this time, and gave 0·1198 grm. $Mg_2P_2O_7$, equal to 3·71 °/₀ P.

Mean of the two chlorine determinations 3·43°/₀ Cl.

This requires 5·41°/₀ Cd, so that there is a deficiency of Cd, probably lost in fusion by volatilisation of Cd.

Filtration of the alkaline solution before precipitation with magnesia mixture, diminishes P by 0·03°/₀, so that it is hardly necessary to effect this filtration of the frequently-observed slight clouds, for the difference would not affect the final result, and if, as is possible, the clouds were

phosphate of calcium, the phosphoric acid might be legitimate, and the calcium only an impurity of the nitre employed in fusion.

Summary :—

C	52·796	Total organic 91·160
H	8·142	
N	1·500	
P	3·690	
O	25·032	
Cd	5·410	8·840
Cl	3·430	
	100·000	100·000

leading to formula $C_{42} H_{75} N P O_{14}$ for organic matter. If one atom of $Cd Cl_2$ were combined with two atoms of organic body, then 9·8°/₀ $Cd Cl_2$ should have been present.

Comparison of the Composition of the Organic Matter with

Per cents of

	Organic matter of oxykephaline with $Cd Cl^2$.	Organic matter in oxykephaloidine with $Cd Cl_2$.	Free peroxykephaline.	Organic matter in lead salt of peroxykephaline
C	58·71	57·91	57·750	56·31
H	9·21	8·82	8·902	8·30
N	1·74	1·64	1·573	1·43
P	4·30	4·04	3·680	3·98
O	26·02	27·45	28·095	29·81

It will thus be perceived that the oxykephaloidine is intermediate between oxykephaline and peroxykephaline in composition in all items except alone hydrogen. This peculiar anomaly, if such it be, must be reserved for future deliberation. The empirical formula expressing the composition of this salt is $2\ (C_{42} H_{75} N P O_{14}) + Cd Cl_2$.

The ethereal solution of this salt was not precipitated by hydrothion gas passed through it.

(b.) *Sub-Group of the Myelines.*

CONTENTS.

Distinction. *General Definition of Myeline.*—In selecting this name for a substance which has not been isolated before, I have to state that it must not be confounded with the matter so named by Virchow, and which is necessarily a mixture of several varieties of phosphorised principles, with several fats and cholesterine. Leading features. The leading features of the principle here to be described will distinguish it with great precision from all similar matters. Colours. When freshly obtained it is white like bleached ivory, but on keeping becomes a little yellowish and waxy. Crystals. It crystallises, from ether or absolute alcohol solution on slow evaporation, in curved needles and scales of a rhombic ovoid shape, which are well seen under the microscope with a power of × 400. When it is in minute crystals it remains powdery even after drying, but when Waxy solid. drying in body after deposition from alcohol and washing by ether, it becomes transparent and waxy, cuts like dry walnut kernel, and when dry can be powdered. Powder, The powder is perfectly white. Emulges with water and dissolves. It emulges with water, and then dissolves, in the manner defined for all phosphorised cerebral principles. The solution iridesces bluish white from polarisation of the minute particles. Reactions. This solution gives the reactions to be described. Dissolves in hot alcohol, less in cold. It dissolves in hot alcohol abundantly, and is deposed on cooling in white tufts, granules, and masses of peculiar appearance, and on slow evaporation in crystalline needles. The alcohol retains much myeline in solution when cold, and gives precipitates with $CdCl_2$ and $PtCl_4$. Dissolves in hot ether. It dissolves in hot ether, and is almost immediately deposited from this solution when its temperature sinks. It is much less soluble in cold ether than in boiling. Contains P It contains more than 3% of phosphorus; Pt Cl^4 salt. gives with $PtCl_4$ a yellow salt, which is insoluble in ether, and soluble with some decomposition in boiling alcohol, from which it is deposited on cooling. Cd Cl_2 salt. It gives with $CdCl_2$ a white salt which is insoluble in ether, but soluble in boiling alcohol. Pb salt. With Pb acetate it gives a white salt, which is insoluble in alcohol and ether, and contains an atom of lead. Myeline is consequently a dibasic acid.

Modes of obtaining Myeline.—It can be obtained directly, without the intervention of precipitants, from the cold alcohol extracts of white matter, by concentration and cooling, redissolving the precipitate, and letting the solution stand for a long time in the cold, when myeline is deposed crystalline. After isolation to be washed with a little ether.

Direct method.

By lead.

The ether extracts of white matter may be precipitated by alcohol, the precipitate emulged with water, treated with lead acetate, washed, and extracted with hot alcohol and ether in succession, when ultimately white myeline lead, of the formula to be given, remains insoluble in these agents. The lead salt decomposed by H_2S in water, and precipitate extracted with hot alcohol, yields white myeline.

Lead salt decomposed.

By $PtCl_4$.

All the mixed phosphorised bodies may be precipitated with $PtCl_4$ from alcohol solution, the precipitate washed and extracted with ether, this will remove kephaline and lecithine, and leave myeline hydrochlorate platinic-chloride, as a yellow body undissolved. The $PtCl_4$ salt must be moistened with ether, and agitated with much water, and washed as long as water extracts either $PtCl_4$ or HCl. Then the residue must be treated with H_2S in water, and washed again until the washings are pure. If they refuse to filter, the mixture must be taken off the filter, put into a bottle with water, and be shaken and triturated, and again filtered. At last the black mass is dried, and then extracted with boiling absolute alcohol. The alcohol on cooling and gradual concentration deposits white crystalline masses of pure myeline.

$PtCl_4$ salt. How decomposed.

Decomposition of of $CdCl_2$ salt.

The $CdCl_2$ salt must also be treated with much water, which removes $CdCl_2$, and must then be treated with H_2S. This process is less convenient than that with Pb or $PtCl_4$. The $CdCl_2$ salt cannot conveniently be decomposed with H_2S in the presence of alcohol or ether, as in that conjunction compounds of myeline with cadmic sulphide are liable to be formed.

Separation from kephaline series.

Differences and Separation from other Cerebral Principles.—Myeline can be separated from kephaline and kephaloidine and allied bodies by the operator using the peculiarity of its being ***very little soluble in cold ether***, in which these bodies and their compounds are easily soluble. The solutions should always be exposed to a very powerful freezing mixture, and filtered through a filter and funnel surrounded with freezing mixture. From ***lecithine*** myeline can be separated by cold absolute alcohol, in which this body is more soluble than myeline; also by cold ether, in which it is also more soluble than myeline. Freezing precipitates in all these cases the myeline more completely than ordinary temperatures.

From lecithine series

From cerebrines.

Myeline can be separated from the principles of the *cerebrine* series by boiling ether, in which the cerebrines are almost insoluble. This separation can also be effected by much boiling alcohol, in which both are largely soluble, but the cerebrines are almost insoluble in cold alcohol, in which therefore myeline would remain dissolved on cooling more readily.

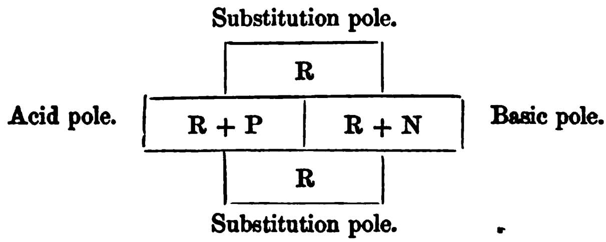
Absolute separation.

An absolute separation of myeline from the other phosphorised principles is best effected by the processes employing lead acetate and platinic chloride, and from cerebrines (as obtained by alcohol process) by extraction with boiling ether, or boiling alcohol and separation after cooling, or by cold benzole.

Constitution.

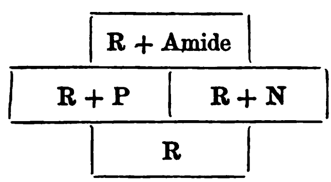
Probable Constitution of Myeline.—It contains four principal, or proximate radicals, of which one is the radical, compound itself, common to all the cerebral phosphorised substance, namely, glycerophosphoric acid. To this is attached a nitrogenised radical, choline or neurine, and

to these radicals are attached two fatty acid radicals, of varying value and composition, but most commonly consisting of margaric acid, with 16 C, or of the amidated form of this acid. Myeline combines with lead like a dibasic acid, with $Pt\,Cl_4$, and $Cd\,Cl_2$, like an ammonium base. From these facts we must attribute to its radicals positions which permit them to act alternately, if not together. These I have endeavoured to represent in the following diagram :—

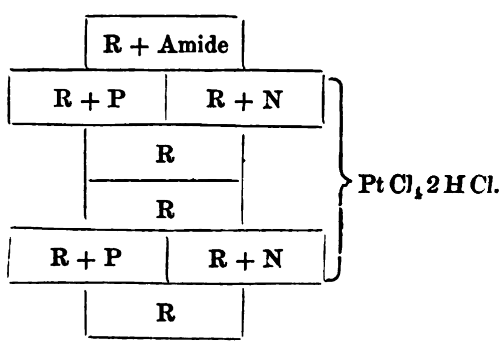


Constitution of amidated forms.

We find sometimes myelines which contain more nitrogen than phosphorus in the proportion of 2 : 1, or 3 : 2, or 5 : 3. In these cases I assume the increase of the nitrogen to be due to the presence of an amidated fatty acid radical, such as I have proved by chemolysis to occur in the rarer forms of kephaline. To such amidated forms I attribute the following constitution :—



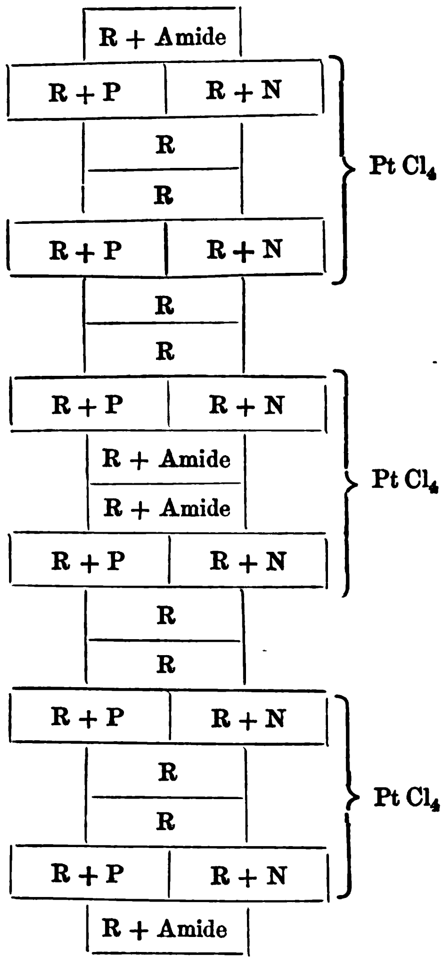
This most simple form I have never directly isolated, but I am compelled to assume its existence by the observation of salts, which could only be explained by any of the following schemes :—



Such a compound was sometimes united with $Pt\,Cl_4$ only, or with $Pt\,Cl_4$ and one $H\,Cl$, or with $Pt\,Cl_4$ and 2 $H\,Cl$, variations which made the preparation and analysis of these bodies extremely difficult and laborious.

But I have also met with compounds which contained when fully expressed six molecules of myeline, of which four were amidated (or two

twice amidated), and which require the following diagram for representation:—



I am yet doubtful whether the formula of myeline as above given must not be doubled, and whether the molecules are of equal value, or if isomeric are not somewhat differently constituted. At least myeline, like kephaline, yields to chemolysis products, in which the constituting radicals are presented in two different forms. The further study, confirmation, or refutation of this hypothesis I must reserve to the future.

Mode of obtaining.

Myeline-Lead.—$C_{40}\ H_{73}\ Pb\ N\ P\ O_{10}$. The ether-solution from white matter, after exhaustion by freezing, was precipitated by alcohol; the bulky precipitate was filtered, washed, and dried in vacuo, and during this process repeatedly pounded in a mortar. It was now dissolved in water, and subjected to fruitless dialysis; it formed a thick, slimy, gummy or starch-like emulsion, in which many small crystals formed like mica. The addition of watery Pb acetate produced a dense curd, which separated easily from fluid; it was placed on a cloth filter and allowed to drip over night. The precipitate was placed in alcohol and

Pb acetate added.

Alcohol extractions.

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Ether extraction.

warmed, whereby little else but water was extracted (one litre alcohol left on evaporation to dryness a little brown matter). More warm strong alcohol now extracted much cholesterine and a little cerebrine Hot boiling absolute alcohol extracted *much* cholesterine and a little yellow smeary lead-salt. The insoluble part was soft, waxy, but on cooling granular. It was now placed in ether, whereby a yellowish fluorescent lead-salt of kephaline was extracted. This latter salt was precipitated by absolute alcohol, deposited as a yellowish oily body, which became hard on standing. This has been treated under kephaline. *A white pulverulent salt* remained insoluble in the ether, was thoroughly washed with ether on the filter, also shaken with ether in a bottle, and again washed on filter. It shrunk much on drying. It was insoluble in benzole.

Insoluble white salt left.

Analyses.

Analyses: — Substance dried at 100° C 1) 0·4648 grm. gave 0·8672 grm. CO_2, equal to 50·88 °/₀ C, and 0·3304 grm. H_2O, equal to 7·89 °/₀ H.

2) 0·535 grm. gave 7 c.c. N at 21° C, & 761 m.m. B. K H O column =19·5 m.m. Hg, equal to 6·18 c.c. normal or 1·44 °/₀ N.

(3.) 0·8961 grm. were fused with caustic soda, sodium carbonate, and nitre; the fuse was dissolved in HNO_3, nearly neutralised, and precipitated by H_2S. The Pb S was filtered off, dissolved in HNO_3, precipitated by H_2SO_4, and ignited. 0·2593 grm. $PbSO_4$ obtained, equal to 19·76°/₀ Pb. In the filtrate P_2O_5 was estimated by Mg mixture, and there was obtained 0·1056 grm. $Mg_2P_2O_7$, equal to 3·28°/₀ P.

Summary of Analyses and Theories:—

	Per-cents.	÷ by At. Wts.	÷ by Pb=1.	÷ by N=1.	÷ by P=1.
C	50·88	4·240	44·63	41·56	40·38
H	7·89	7·890	83·05	77·35	75·13
Pb	19·76	0·095	1·00	0·93	0·90
N	1·44	0·102	1·07	1·00	0·97
P	3·28	0·105	1·10	1·02	1·
O	16·75	1·046	11·01	10·25	9·96
	100·00				

The organic body in the salt = 100 − 19·76 = 80·24.
Per-cents. of elements found in organic body and theories:—

		÷ by At. Wts.	÷ by N=1.	÷ by P=1.
C	63·409	5·2840	41·24	40·09
H	9·833	9·8330	76·76	74·60
N	1·794	0·1281	1·	0·90
P	4·087	0·1318	1·02	1·
O	20·874	1·3046	10·18	9·89
	99·997			

There are thus arguments at hand for atomic weights with from 40 atoms to 44 atoms of carbon; but the combined metals and salts are under all circumstances less to be relied upon for atomic weight determinations of the phosphorised principles than the constitutional elements P and N. These latter, therefore, prevail in my opinion as determinants, particularly as they agree well with each other. I therefore

accept $C_{40} H_{73} N P O_{10}$ as the formula of the body combined with lead, and adding 2 H in place of Pb, the formula of the free body will be $C_{40} H_{75} N P O_{10}$.

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	Theory of		Found.
Elements.	At. Wts.	Per-cents.	
40 C	480	63·15	63·409
75 H	75	9·86	9·833
1 N	14	1·84	1·794
1 P	31	4·07	4·087
10 O	160	21·05	20·874
	760		

Decomposition of Pb Salt by H_2S.—A portion was decomposed by $H_2 S$ while suspended in ether. The ethereal filtrate from the Pb S deposited a white flaky matter on being shaken, which increased in quantity on standing. It was allowed to go to dryness spontaneously, and left an abundant white residue, which was soft, and smelled peculiarly. It fused above 100, was perfectly fused about 125° to 130°, and on cooling was quite solid again at 100°. On being heated further it cracked and spirted, then gave off strong smelling fumes, burnt with a white luminous flame, and left a charcoal difficult to incinerate. Fused with nitre and soda, and the fuse dissolved in $H N O_3$, the tests for lead gave negative results, but the tests for $P_2 O_5$ gave evidence of abundance; so that the $H_2 S$ treatment removed all the lead.

Pb S contains yet myeline.

The supposed Pb S, on heating, fused, and gave off carbonaceous vapours, and behaved in such a manner as to indicate that it did yet contain much organic matter. Therefore much ether, or better, boiling alcohol, will be required to extract all myeline from the Pb S.

The entire quantity of finely-powdered lead salt was now placed in absolute alcohol, and decomposed with $H_2 S$ while being heated in a water-bath, filtered hot, and extracted with hot alcohol. The alcohol extract, on cooling, deposited a crystalline mass. This was recrystallised from absolute alcohol, when a tendency to stearoconotise became evident in the deposit, but all ultimately dissolved with the aid of hot ether, and the first purest portion of crystals was analysed.

Analyses.—Dried at 100° C; became coloured on surface.

(1.) 0·6756 grm. gave 0·1000 grm. $Mg_2 P_2 O_7$, equal to 4·17% P.

(2.) 0·4266 grm. gave 0·9800 grm. $C O_2$, = 62·651% C, and 0·3970 H_2O, = 10·340 % H.

(3.) 0·5000 grm. gave 9·c.c. gas at 760 m.m. B, and 20°5 C; K H O=36 mm. Hg equal to 8 c.c. normal=2·00% N.

Summary and Computation:—

	Per-cents.	÷ by At. Wts.	÷ by P=1.
C	62·651	5·221	39·0
H	10·340	10·340	77·1
N	2·000	0·142	1·
P	4·170	0·134	1·
O	20·829	1·301	9·7

The isolated myeline thus exhibits the formula $C_{39} H_{77} N P O_9$, being the same as that of the non-amidated molecule in several Pt Cl_4 and Cd Cl_2 salts from ox and man, to be described later.

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Myeline-Platinic Chloride, Modes of preparing.—A quantity of a mixture of myeline and lecithine from W. M. was placed in hot water and diffused and dissolved. The solution was filtered through force filter, acidified by H Cl and Pt Cl_4 added. The almost colourless gelatinous precipitate floated in the froth produced by shaking. The liquor was syphoned away from underneath the precipitate, and the latter thrown on a filter. On addition of a little water it immediately began to swell, and would not filter. It was therefore transferred to a beaker and agitated with alcohol of 85°/₀, whereby it became condensed. The liquid was again removed and absolute alcohol given to the precipitate and the mixture shaken. This caused a great condensation of the precipitate, which was thrown on a filter, washed with absolute alcohol, isolated, and somewhat dried. It was now placed in a considerable quantity of ether, as previous experiment had shown that if but little ether was employed there would be difficulty in filtration. A considerable quantity of a *yellow salt remained undissolved*, being the *compound of myeline and Pt* Cl_4, while the yellow filtrate contained the *lecithine salt*, which was isolated by precipitation with absolute alcohol.

Alcohol treatment.

Ether treatment.

Separation of salts.

Three further preparations. Modified process.

Three further preparations were made with this modification of the process, that the precipitates as obtained by H Cl and Pt Cl_4 were, without being heated with water, immediately after separation from the first mother liquor agitated with an equal bulk of cold absolute alcohol and a few drops of Pt Cl_4; then washed with absolute alcohol, and then separated by ether. The insoluble precipitates from preparation 1 and 2 were united with each other, as were the insoluble ones from preparations 3 and 4, and analysed separately.

Analysis of Preparation 1 *and* 2.—After drying in vacuo lost 2·7°/₀ at 95° C.

(1.) 0·9027 grm. fused with caustic soda, sodium carbonate, and nitre, &c. left 0·05440 grm., equal to 6·026°/₀ Pt. Further, 0·1948 grm. Ag Cl giving 4·569°/₀ Cl. The Pt found requires 4·334 Cl, so that there is only 0·230°/₀ Cl. to be placed on account of any H Cl or, in other words, the compound is not a hydrochlorate. There were further obtained 0·1078 grm. $Mg_2 P_2 O_7$, corresponding to 3·334°/₀ P.

Summary :—

	Per-cents.	÷ At. Wts.	÷ by Pt=1.
Pt	6·026	0·0306	1
Cl	4·564	0·1285	4·19
P	3·334	0·1075	3·51

There was therefore an irrationality between the Pt Cl_4 and the phosphorus, showing that if two molecules of myeline were in combination with Pt Cl_4, one and a half molecule, or at least one molecule more of myeline must have been combined with this Pt salt. The body was herefore not any further analysed.

Analysis of Preparation 3 *and* 4.—

Pt. (1.) 0·9311 grm. fused, &c. gave 0·0598 grm. Pt, equal to 6·442°/₀
Cl Pt. Further, 0·2468 grm. Ag Cl = 6·551°/₀ Cl. Further, 0·1208 grm. $Mg_2 P_2 O_7$ = 3·619°/₀ P.

N (2.) 0·5680 grm. gave 10·6 c.c. gas at 13° C. and 777 mm. B.
C. K H O = 163 mm., equal to 10 c.c. normal = 2·202°/₀ N.

H. (3.) 0·5120 grm. gave 1·066 CO_2 = 56·782°/₀ C and 0·447 H_2O = 9·992°/₀ H.

It is therefore evident that the Pt : Cl in this case is nearly as 1 : 6, but that both P and N stand in no direct ratio to $Pt\,Cl_4$.

Summary of Analyses :—

	Per-cents.		÷ by At. Wts.	÷ by Pt = 1
C	56·782	87·007	4·7314	145·1
H	9·992		9·9921	—
N	2·202		0·1572	4·82
P	3·619		0·1167	3·58
O	14·412		0·9007	—
Pt	6·442	12·993	0·0326	1·
Cl	6·551		0·1845	5·66
	100·000			

Calculated Per-centage for Organic Molecule :—

	Per-cents.	÷ by At. Wts.	÷ by P = 1.	P = 3.
C	65·2666	5·4388	40·52	,,
H	11·4850	11·4850	85·58	,,
N	2·5310	0·1810	1·34	4·
P	4·1600	0·1342	1·00	3·
O	16·5574	1·0348	7·71	
	100·0000			

Disregarding small discrepancies a formula $C_{41}\,H_{85}\,N\,P\,O_8$ might be derived, but the nitrogen, as in other cases of first salts, is too high, being N : P = 4 : 3. If we assume three molecules of organic principle to be present, and one to contain an amidated radical, we obtain the following hypothesis :

$$\begin{array}{l} C_{40}\,H_{86}\,N_2\,P\,\,O_8 \\ C_{41}\,H_{85}\,N\,\,P\,\,O_8 \\ C_{41}\,H_{85}\,N\,\,P\,\,O_8 \\ \hline C_{122}\,H_{256}\,N_4\,P_3\,O_{24} \end{array}$$

On comparison of this myeline with that in the lead salt it will be seen that the hydrogen is by 10 atoms higher, and the oxygen by two atoms lower. The body in the Pb salt is therefore properly *oxy-myeline.*

Solution in and Recrystallisation from Boiling Alcohol. Formation of Apomyeline and $Pt\,Cl_4$

The foregoing analysed salt (prep. 1132, 3rd and 4th portion) was now heated with boiling alcohol, whereby most of it was dissolved and reprecipitated on cooling. The insoluble part was put aside. The recrystallised compound gave on analysis the following results :—

(1.) 0·4220 grm. gave 0·8430 grm. $C\,O_2$ = 54·481% C, and 0·3636 grm. $H_2\,O$ = 9·573% H.

(2.) 0·5536 grm. gave 13 c.c. gas at 19° C, and 763 m.m. B. K H O = 16 m.m. Hg = 11·6 c.c. normal = 2·621% N.

(3.) 1·003 grm. heated by fusion method gave 0·0858 grm. Pt = 8·554% Pt. Further, 0·3662 grm. Ag Cl = 9·032% Cl, and 0·1260 grm. $Mg_2\,P_2\,O_7$ = 3·507% P.

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Summary of Analyses :—

	Per-cents.	
C	54·481	
H	9·573	
N	2·621	
P	3·507	
O	12·232	
Pt	8·554	17·586
Cl	9·032	
	100·000	

Comvutation of Free Molecule :—

	Per-cents.	÷ by At. Weights.	by P = 1.
C	66·101	5·508	40·2
H	11·615	11·615	84·7
N	3·178	0·227	1·6
P	4·255	0·137	1·
O	14·837	0·927	6·7
	99·986		

The differences in the composition of the salts before and after solution in boiling alcohol are best seen in the following comparison.

	The Salt before Solution.		The Salt after Solution in Hot Alcohol.	
C	56·782		54·481	
H	9·992		9·573	
N	2·202		2·621	
P	3·619		3·507	
O	14·412		12·232	
Pt	6·442	12·993	8·554	17·586
Cl	6·551		9·032	
	100·000		100·000	

A remarkable increase in the per-centage of $Pt\ Cl_4$ becomes at once apparent; the other elements also change, but in a differing ratio, not wholly determined by the increase of the attached metallic salt. This change is perceived better upon the organic molecules, compared in their free state.

	Before.	After.	Apomyeline, Man.
C	65·2666	66·101	67·01
H	11·4850	11·615	11·35
N	2·5310	3·178	3·00
P	4·1600	4·255	3·23
O	16·5574	14·837	14·649
			+ Cl 0·761
	100·0000	100·000	

Carbon and hydrogen have slightly risen; nitrogen has risen by one-fifth of the quantity in the first salt, or from 5 to 6; phosphorus has

risen a little, and oxygen has greatly fallen. These changes seem to have reached a certain climax in the (human) apomyeline (from $Pt\ Cl_4$ salts, boiled in alcohol), which was examined in the free state. They indicate that myeline has perhaps a much higher atomic weight than that shown in the above empirical formula, and under the influence of acid and metallic salts in alcohol gives up certain proximate component nuclei, containing P, while retaining all or most of its N.

Comparison of this body with Apomyeline (man.) $C_{52}\ H_{106}\ N_2\ P\ O_9$.—The theory of the $Pt\ Cl_4$ salt from ox (boiled), comes very close to this, except in the P.

Theory. Atoms.		Per cents.	Found.
104 C	1248	54·80	54·481
212 H	212	9.31	9·573
2 P		2·72	3·507
4 N		2·46	2·621
18 O			12·232
1 Pt		8·69	8·55
6 Cl		9·35	9·03

The relation of $Pt\ Cl_4$, Cl_2, and N_4, make this compound very important; if the difference in the P can be hereafter explained, it may perhaps be expressed by the formula—

$$\left.\begin{matrix} C_{52}\ H_{106}\ N_2\ P\ O_9\ Cl \\ C_{52}\ H_{106}\ N_2\ P\ O_9\ Cl \end{matrix}\right\} Pt\ Cl_4$$

Myeline-Platinic-Chloride from Ox. W.M. (preparation 1188).—This salt was prepared from the cold alcoholic extracts as above described, and was insoluble in ether. It was dried at from 70° to 80° C; the particles lost their light yellow colour, and adhered to each other, but were not otherwise altered.

Analyses:—(1.) 0·963 grm. fused with caustic soda, nitre, and potash carbonate, gave 0·0728 grm. Pt = 7·559 °/₀ Pt; further 0·3360 grm. Ag Cl = 8·630 °/₀ Cl; and 0·115 grm. $Mg_2\ P_2\ O_7$ = 3·334 °/₀ P.

(2.) 0·4716 grm. burned with chromate, &c., gave 0·8984 grm. $C\ O_2$ = 51·955 °/₀ C, and 0·380 grm. $H_2\ O$ = 8·952 °/₀ H.

(3.) 0·549 grm. gave 11·5 c.c. gas at 762 m.m. B and 20° C. KHO = 16·7 m.m. Hg, equal to 10·2 c.c. normal = 2·324 °/₀ N.

Summary of Analyses:—

C	51·955	83·811
H	8·952	
N	2·324	
P	3·334	
O	17·246	
Pt	7·559	16·189
Cl	8·630	
	100·000	100·000

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Computation of °/₀s of free organic body :—

	Per cents.	÷ At Weight.	÷ by P = 1.
C	61·990	5·166	40·3
H	10·681	10·681	83·4
N	2·772	0·198	1·5
P	3·978	0·128	1·0
O	20·579	1·286	10·0

leading to formula—

$$\left.\begin{matrix} C_{40}\,H_{83}\,N\ \ P\,O_{10} \\ C_{40}\,H_{82}\,N_2\,P\,O_{10} \end{matrix}\right\} = C_{80}\,H_{165}\,N_3\,P_2\,O_{20}.$$

H_2S treatment of $Pt\,Cl_4$ myeline.

Decomposition of the 1*st and* 2*nd Insoluble Platinic Chloride Myeline Compound by H_2S, and Recovery of the Free Myeline in the Pure State.*—This salt, the partial analysis of which has been described above, was triturated in a mortar with water to an impalpable powder, mixed with more water, and treated with H_2S in excess. Time was allowed for the complete action of the H_2S, and filtration was not effected until the mass had stood in a stoppered bottle for several days. The filtrate contained apparently no organic matter, and did not give the reactions of myeline. The washed and drained precipitate was now digested in boiling alcohol for some time, and filtered hot. The filtrate was slightly yellowish, and contained the free myeline as shown by the following tests :—

Reactions of alcohol solution.

On evaporation a portion left a white residue.
With water the alcohol solution became milky without giving precipitate.
Aqueous $Pt\,Cl_4$ gave an abundant yellow granular precipitate.
$Pt\,Cl_4 + H\,Cl$ also gave the foregoing precipitate, but $H\,Cl$ alone none.
$Ba\,Cl_2$ gave a good dense precipitate.
$Ba\,H_2\,O_2$ gave a somewhat gelatinous precipitate.
Aqueous $Cd\,Cl_2$ gave a bulky, but swelled precipitate.
Alcoholic $Cd\,Cl_2$ gave a good bulky precipitate.
Aqueous $Zn\,Cl_2$ gave a good white precipitate.

The bulk of the solution was now allowed to evaporate spontaneously, when it deposited minute *crystals, characteristic of myeline.* It was subsequently added to a similar preparation derived from the union of several $Pt\,Cl_4$ compounds, also decomposed by the H_2S process, and further studied as will be described.

Myeline-Platinic-Chloride from Ox Buttery Matter.—The buttery matter was dissolved in ether, and alcoholic $Pt\,Cl_4$ added. A yellow precipitate ensued, insoluble in ether, with which it was washed. Weight 4·7 grm., and gave on analysis the following results. Lost in air-bath at 70–80° C. 1·44 °/₀.

Analyses. Pt.

(1.) 1·2359 grm. were gradually introduced into a previously fused mixture of nitre and sodium carbonate. It was ascertained that in this manner some phosphorus and much chlorine were lost. Therefore the Pt alone was determined and found to be equal to 10·48 °/₀ Pt.

Pt. Cl.

(2). In this experiment 1·0484 grm. were boiled down with caustic soda leye, made from metallic sodium and nitre, in a platinum crucible, and heated to fusion, &c. There were obtained: Pt = 10·36 °/₀ ; Cl = 10·89 °/₀ ; P = 3·31 °/₀. We have therefore here almost exactly one atom of Pt to six atoms of Cl, *i.e.*, upon 197·4 Pt 213 Cl required, and 214·9 found.

(3.) 0·5933 grm. gave 1·0867 CO_2 = 49·94 °/$_o$ C and 0·4588 H_2O, equal to 8·36 °/$_o$ H. — C. And H.

(4.) 0·7164 grm. gave 12·8 c.c. N gas, normal, equal to 2·23 °/$_o$ N. — N.

(5.) 0·5722 grm. gave 11·755 c.c. N gas, normal = 2·57 °/$_o$ N. Mean 2·4 °/$_o$ N. — N.

Summary of Analyses :—

			÷ by At. Wt.	÷ by Pt = 1.
C	49·94	78·69	4·1658	79·1
H	8·36		,,	,,
N	2·40		0·1714	3·25
P	3·31		0·1067	2
O	14·68		,,	,,
Pt	10·42	21·31	0·0526	1
	10·89		,,	6
	100·00			

Computation of Organic Molecule :—

	Per cents.	÷ by At. Wt.	÷ by P = 1.		M. Wt. P = 1.
C	63·46	5·288	39·1	52·	468
H	10·624	10·624	78·7		77
N	3·05	0·217	1·6	2·1	14
P	4·20	0·135	1·		31
O	18·67	1·166	8·6		144
	100·004				734

The $Pt\,Cl_4 + 2\,HCl$ is in excess of that molecule; 21·31 : 78·69 = 411 : 1517; $\frac{1517}{2} = 758·5$. The nitrogen is too high for any simple formula, and stands to P = 3 : 2, or 5 : 3. We have therefore here also perhaps an amidated radical in one out of two molecules, and obtain as simplest hypothesis :—

$$\left.\begin{matrix} C_{39}\,H_{78}\,N_2\,P\,O_9 \\ C_{39}\,H_{77}\,N\,\;P\,O_9 \end{matrix}\right\} + (HCl)_2 + Pt\,Cl_4.$$

Myeline-platinic chloride, $C_{78}\,H_{163}\,N_3\,P_2\,O_{16}$, Cl_2, $Pt\,Cl_4$, from ox buttery, preparation Nro. 1202.—This compound was insoluble in ether; soluble in benzole.

Analyses.

(1.) 0·9473 grm. dried at 60–75° C. were subjected to fusion, and yielded,—

(*a*) 0·089 grm. equal to 9·395 °/$_o$ Pt.
(*b*) 0·3840 grm. Ag Cl = 10·026 °/$_o$ Cl.
(*c*) 0·1164 grm. $Mg_2\,P_2\,O_7$ = 3·431 °/$_o$ P.

(2.) 0·4612 grm. gave 9·5 c.c. gas at 20° C. and 764 m.m. B. KHO column = 16·7 m.m. Hg = 8·5 c.c. gas normal, or 2·305 °/$_o$ N.

(3.) 0·4830 grm. gave 0·9062 grm. CO_2, equal to 51·168 °/$_o$ C; and 0·3900 grm., H_2O equal to 8·971 °/$_o$ H.

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Summary of Analyses.

C	51·168	80·579
H	8·971	
N	2·305	
P	3·431	
O	14·704	
Pt	9·395	19·421
Cl	10·026	
	100·000	100·000

In this salt Pt : Cl = 1 : 6. But the Pt Cl_6 is about 2·5 per cent. too low when compared with the requirements of the computed free body. For the atomic weight of this 729 + 205·2 (being the molecule, with P = 1 + ½ molecule Pt Cl_6) requires 21·96 °/₀ of Pt Cl_6.

Computation of Organic Body free from Pt Cl_6.

	°/₀ s.	÷ by At. Wts.	÷ by P = 1.
C	63·500	5·291	38·6
H	11·133	11·133	81·2
N	2·865	0·204	1·489 (say 1·5)
P	4·257	0·137	1·0
O	18·245	1·140	8·3
	100·000		

These data lead necessarily to the empirical formula $C_{78}\ H_{162}\ N_3\ P_2\ O_{16}$ for the free substance, and with the aid of the hypothesis applied to other salts to formula—

$$\left.\begin{matrix} C_{39}\ H_{81}\ N\ P\ O_8\ Cl \\ C_{39}\ H_{83}\ N_2\ P\ O_8\ Cl \end{matrix}\right\} Pt\ Cl_4.$$

Stress must be laid upon the fact that here again N : P = 3 : 2.

Myeline Cadmic Chloride Salts from Ox Buttery.—The salts described in the following were all obtained from the buttery matter by the following process:—The matter was dissolved in ether, and precipitated by alcohol. No freezing or other artificial low temperature was employed. The solution, separated from the precipitate, was treated with Cd Cl_2 in alcohol; a voluminous white precipitate fell, which, after isolation and pressing, was exhausted with ether. The portion which remained *insoluble in ether* is the one here to be considered. It was soluble in boiling alcohol, and deposited from this solution on cooling perfectly white. It dissolved in hot benzol, and from this solution no deposit ensued on cooling. The fluid was red coloured, and had a green fluorescence. It was precipitated, whilst warm, with alcohol of 85 °/₀, filtered, washed with much alcohol, and pressed in a cloth. This process was repeated twice more with all formalities. The purified salt was next extracted with alcohol of 85 °/₀ at 45° C., by which a small quantity of salt was separated. The salt which was not dissolved is the one analysed below. (Further experience showed that absolute alcohol dissolved and re-deposited the whole of the compound.) As the product constituted the largest quantity of Cd Cl_2 salt obtained in this and similar processes, it was termed "principal cadmium salt, insoluble in ether."

Soluble in hot alcohol.

Solution in benzol and precipitation by spirit.

Analyses.

(1.) 0·9462 grm. fused with caustic soda and nitre, &c., yielded 0·3041 grm. Ag Cl, equal to 7·94 °/₀ Cl. and 0·1104 grm. $Mg_2 P_2 O_7$ equal to 3·26 °/₀ P.

(2.) 0·9500 grm. gave 0·2900 grm. Ag Cl = 7·55 °/₀ Cl, and 0·1132 grm. $Mg_2 P_2 O_7$ = 3·32 °/₀ P.

(3.) 0·8950 grm. fused, &c., and dissolved in dilute H Cl; Cd precipitated as Cd S: the latter dissolved in H Cl; the solution evaporated to drive off excess of acid, and then precipitated by $Na_2 CO_3$; precipitate ignited left 0·1288 grm. Cd O, equal to 12·59 °/₀ Cd.

Accidents.

It was found that the greatest care is necessary in this mode of analysis to prevent three kinds of accident—(1) volatilization of Cd; (2) formation of alloy of Cd with Pt; (3) excess of S in Cd S, which makes it impracticable to determine the Cd as sulphide.

(4.) 0·4186 grm. gave 0·7696 grm. CO_2 = 50·14 °/₀ C, and 0·3120 grm. H_2O = 8·28 °/₀ H.

(5.) 0·634 grm. gave 9·2 c.c. gas at 19° C. and 757 m.m. B. KHO= 16 m.m. Hg = 8·1 c.c. normal, or 1·59 °/₀ N.

Summary.

	Found in 100.	
C	50·14	79·47
H	8·28	
N	1·59	
P mean	3·29	
O	16·37	
Cl	7·94	20·53
Cd	12·59	
	100·00	

Computation of Percentage and Formula of Organic Molecule.

	°/₀	÷ by At. Wts.	÷ by P = 1.
C	63·09	5·257	39·52
H	10·41	10·41	78·27
N	2·00	0·142	1·06
P	4·13	0·133	1·
O	20·59	1·286	9·66
	100·00		

H_2S dissolves Cd Cl salt.

Behaviour of this Cd Cl_2 salt with $H_2 S$ in Ether.—A little of this salt was suspended in ether, and a few bubbles of hydrothion were passed through the mixture. *The precipitate immediately dissolved,* and a bright yellowish red solution resulted. It was thus evident that this peculiarity, which I had observed on many Cd Cl_2 precipitates before, was a general feature of these salts; *they could not be decomposed in ether by $H_2 S$,* because the Cd S formed passed into solution instead of being, as had been expected, precipitated. The solution was divided in three parts: in one alcohol threw down a yellow flaky precipitate, which readily subsided; in a second portion water threw down a gelatinous swollen mass, not unlike yelk of egg, which floated on the top of the solution; in a third portion ammonia behaved much like water, except that the whole solution became nearly solid. I have shown elsewhere that the yellow precipitate which alcohol produces in the ether solution contains the organic molecule of the Cd Cl_2 precipi-

No Cd S precipitated.

Alcohol precipitates yellow salt.

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tate, cadmium, chlorine, and sulphur. We may, therefore, consider that in the ethereal solution the compound behaves *like a mercaptan*, and being itself sulphurised for the time, has the power to combine with or hold in solution a metallic sulphide.

Similarity to mercaptans.

The salt, though insoluble in ether, is soluble in ether acidified with HCl. In this solution, also, no precipitate is produced by H_2S; but it assumes a yellow colour, and water produces in it a yellow gelatinous emulsion, which persists for weeks, if not treated with large volumes of ether. The yellow ether solution, on spontaneous evaporation, leaves a yellow residue behind.

$PtCl_4$ applied to mother liquor of W. M.

Myeline Cadmic Chloride from Alcoholic Extracts of Human Brains after Removal of White Matter and Platinic Chloride Precipitates.—In some of my researches I applied $PtCl_4$ to the mother liquor of white matter in the hope of thereby effecting a precipitation of phosphorised bodies. But the results obtained from large quantities of material were insignificant. Much platinum remained in solution, and was partially recovered by the addition of ammonia. (The precipitate contained other matters, and in particular gave reactions of a metal not hitherto known in science.) The entire solution was now concentrated by distillation, allowed to cool, and the deposited cholesterine removed. The liquid was treated with a large volume of water, filtered, and the filtrate evaporated to about ½ volume. A dark smeary deposit appeared in the evaporating dishes, which was added to the residue of the first filtration on filter. These residues were dissolved in ether. This solution may in effect be considered as *a solution of buttery matter in ether, to which $PtCl_4$ has been added.*

Distilled.

Mixed with Aq.

Precipitates dissolved in ether.

H_2S treatment.

This solution was now treated with H_2S to remove $PtCl_4$, but this was only partially successful, for although a precipitate ensued, yet the fluid remained black, and retained Pt; it was therefore warmed on water bath, and CO_2 passed through it to drive off a large excess of H_2S. More than an equal volume of alcohol was now added to it, whereupon a dark brown bulky precipitate fell down; this was ascertained to contain kephaline, myeline, and lecithine, but the kephaline in prevailing amount. The ether alcohol filtrate contained the matter which gave the $CdCl_2$ salt to be described.

Alcohol precipitates several matters.

$CdCl_2$ precipitates.

The solution was distilled to remove the ether, and the residue allowed to stand to deposit cholesterine. To the filtrate from this latter alcoholic $CdCl_2$ was added, whereby an abundant white precipitate was produced, which was washed with alcohol and dried. It was next extracted with alcohol at 45° C to remove any cerebrine. It was found to be insoluble in ether, but yielded to this solvent a quantity of matter, which was again precipitated by the addition of alcohol. (Kephaline and lecithine $CdCl_2$.) All these collateral precipitates were not any further investigated on account of the difficulty of freeing them from cerebrine and cholesterine. But the $CdCl_2$ precipitate, which remained insoluble in ether (though it dissolved in ether with the aid of H_2S, and the solution gave a yellow precipitate of an organic CdS compound with alcohol), was analysed with the following result.

H_2S dissolved precipitate in ether.

Analyses.—(1.) 0·9660 grm. gave 0·3751 $Ag = 9·61\%$ Cl and 0·1122 $Mg_2P_2O_7 = 3·24\%$ P.

(2.) 0·7268 grm. gave 0·1426 grm. CdS, equal to 15·25% Cd; 0·2827 grm. $AgCl = 9·61\%$ Cl; and 0·0820 grm. $Mg_2P_2O_7 = 3·15\%$ P.

(3.) 0·5576 grm. gave 0·979 grm. $CO_2 = 47·88\%$ C, and 0·3868 grm. $H_2O = 7·71\%$ H.

(4.) 0·5137 grm. gave 8·3 c.c. gas at 17·0 C and 762·5 m.m. B, &c., equal to 7·47 c.c. N normal $= 1·81\%$ N.

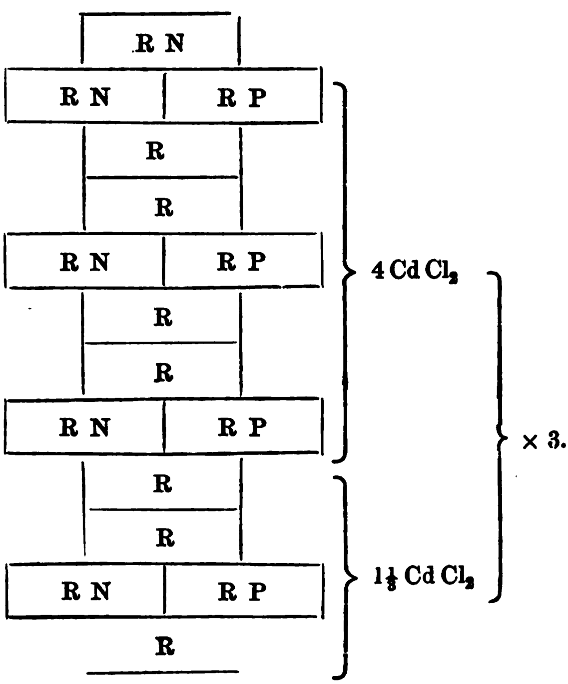
Summary of Results :—

			÷ by At. Wgts.	÷ by P = 1.	P = 4.
C	47·88	75·14	3·99	38·73	
H	7·71		7·71	74·8	
N	1·81		0·129	1·25	5·00
P	3·20		0·103	1·	4
O	14·54		0·908	8·81	
Cl	9·61	24·86	0·270	2·62	10·48
Cd	15·25		0·136	1·32	5·28
	100·00				

We thus find that Cd : Cl = 1 : 2, but the $Cd\,Cl_2$, as compared to the organic molecule, is about one third (of its theoretical quantity) in excess of its required quantity. Deducting the $Cd\,Cl_2$, and calculating organic molecule we obtain :—

		÷ by At. Wgts.	÷ by P = 1.	P = 4.
C	63·72	5·315	38·79	—
H	10·26	10·26	74·89	—
N	2·40	0·1714	1·25	5
P	4·25	0·137	1·	4
O	19·37	1·21	8·81	—
	100·00			

If we assume that of every four molecules one contains an amidated radical besides the ammonium radical, we obtain the following scheme :—



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This salt was extracted with benzole after analysis, in which it swelled, but did not dissolve; some coloured matter was extracted. It is therefore different from the principal ox Cd Cl_2 salt, which was repeatedly dissolved in benzole and precipitated by alcohol, but is nevertheless very similar in composition.

Ox, Cd Cl_2 salt. $C_{39} H_{75} N P O_9 + Cd Cl_2$.
Man, Cd Cl_2 salt. $C_{39} H_{75} N P O_9 + Cd Cl_2 + \frac{1}{3} Cd Cl_2$.

There remain to be inquired into, and to be analysed if sufficient material can be collected:

(*a.*) The Cd Cl_2 salt extracted by ether.
(*b.*) The Cd Cl_2 salt extracted by alcohol at 45° C.
(*c.*) The body extracted by benzole.
(*d.*) The cause of the insolubility in benzole, and whether it is the excess of Cd Cl_2 or not.
(*e.*) The organic body combined with the Cd Cl_2 after removal of this salt.
(*f.*) The chemolytic products of the organic body.

Myeline Cadmic Chloride, from Ox White and Buttery Matter, and Cerebrine.—This myeline was a mixture of various specimens, similarly prepared. White matter, extracted with cold alcohol and ether; also buttery in the same manner; further, cerebrine deposited by ether extracts of white matter, were found to contain much phosphorus. The whole of the matters were therefore dissolved in hot absolute alcohol, and the solution allowed to cool. The filtrate was a saturated solution of myeline. This was allowed to stand, and deposited some gelatinous kerasine, which was filtered off. To the colourless clear solution Cd Cl_2 was added as long as a precipitate was produced. The white deposit was washed and redissolved in boiling absolute alcohol. Most of it dissolved, and was deposited on cooling after filtration on hot funnel. Some remained insoluble, and is here not any further considered. Some remained dissolved in the absolute alcohol after cooling, and was obtained after distillation of the alcohol. Some remained dissolved in the very last mother liquor. The following salt is the one deposited on cooling of the alcohol solution: white masses, little waxy, easily powdered, dried in vacuo.

Insoluble part.

Analyses.—(1.) Determination of phosphorus. 2·1008 grm. were fused with caustic soda, nitre, and carbonate; the residue was dissolved in H Cl, and the Cd removed by hydrothion. This yielded only 0·2272 Cd O, equal to 9·463°/$_0$ Cd, so that the loss surmised during the experiment was verified. To the acid filtrate $N H_4 H O$ was added to alkalinity, whereby a precipitate was produced, proved subsequently to consist of calcium phosphate, with a trace of iron; this weighed 0·0178 grm., and its phosphorus was calculated as that of $Ca_3 P_2 O_8$ = 0·00342°/$_0$ P. To the filtrate magnesia mixture was now added, and the process yielded 0·2418 grm. $Mg_2 P_2 O_7$, equal to 3·214°/$_0$ P, which with the P in the lime salt, is 3·2174°/$_0$ P nett.

Nitric acid process.

(2.) Cd Cl and P determination by HNO_3 method. To avoid the loss of Cd, 2·0238 grm. of the salt were boiled with excess of nitric acid and silver nitrate 1 grm., in a long-necked assay flask, until destroyed. At one time the solution was bluish, and ultimately colourless; the Ag Cl deposited, and a little oil floated on top, which became solid on cooling. This remained with the Ag Cl, and caused some difficulty in the ignition of the latter, which required treatment with $H N O_3$ and H Cl, after which the Ag Cl behaved normally. It weighed

0·5533 grm., equal to 6·754% Cl. The Cd S next precipitated, and transformed into oxyde, with the precaution of treating the paper filter with HNO_3 previous to ignition, gave 0·2928 CdO = 12·60 % Cd. This latter figure requires 7·99% Cl, whereas the 6·754 % Cl found require only 10·65/ Cd. We have therefore here the Cd undoubtedly Cl. slightly in excess of the Cl, or, in other words, a loss of chlorine. The Cd. acid solution was now treated with excess of NH_4HO, and gave the same precipitate as analysis 1. It was not filtered off. The phosphoric acid was now precipitated by magnesia mixture, and yielded 0·1048 grm. $Mg_2P_2O_7$, equal to 1·466 % P. (See notes below.) P.

(3.) 0·4312 grm. gave 0·808 grm. CO_2 = 51·104% C, and C. 0·3466 grm. H_2O = 8·931% H. H.

(4.) 0·5460 grm. dried at 80° C. during four hours, gave 12 c.c. gas N. at 20° C, and 767 m.m. B. K H O column = 18 m.m. Hg = 10·77 c.c. normal, or 2·46% N.

(5). Determination of Cl and P by fusion method. 1·432 grm. gave 0·4850 grm. Ag Cl equal to 8·37 % Cl and 0·1720 grm. $Mg_2P_2O_7$ equal to 3·354 % P.

Note on Analytical Methods.—There being a great deficiency of P in analysis 2), the Ag Cl was searched for this element. It was dissolved in ammonia and nitric acid alternately applied, and the Ag Cl ultimately filtered from the acid solution. The latter showed by molybdate test unmistakeable evidence of the presence of P. It is therefore probable that the fatty body which remained and was burned with the Ag Cl contained P. Further, the ultimate mother liquor of the magnesia precipitate was evaporated to dryness and fused with nitre. The solution in water with the molybdate test showed the presence of a large amount of P. *It is therefore clear that by this treatment with nitric acid, phosphorus in two forms may escape detection, and that the process is unsuitable for the determination of this element.* The uncertain and varying results of Couerbe and Köhler receive by this fact a partial explanation. On the other hand, it is proved that the method of fusion with nitre and sodium carbonate after previous digestion with caustic soda leye gives the whole of the chlorine and phosphorus contained in the salt, but is liable to engender a loss of cadmium. This metal seems however to be completely isolated by the nitric acid process, and I have therefore come to the resolution to determine Cd by the nitric acid method in one experiment, in which Cl and P are left out of consideration, and to determine P and Cl by the fusion method in another experiment in which Cd is left out of consideration.

Summary of Analyses :—

	Per cents.		
C	51·104		79·030
H	8·931		
N	2·460		
P	3·285	mean of $\begin{cases} 3·217 \\ 3·354 \end{cases}$	
O	13·250		
Cl	8·370		20·970
Cd	12·600		
	100·000		100·000

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Computation of Organic Molecule :—

Per cents.		÷ by at ws.	÷ by P=1.	P=2.	P=3.
C	64·66	5·38	40·2		
H	11·30	11·30	84·4		
N	3·11	0·2221	1·65	3·30	4·95
P	4·15	0·1338	1·00	2·	3·
O	16·78	1·05	7·84		
	100·00				

Again this body is not a simple, but a compound salt, containing perhaps three molecules of myeline, in two of which an amidated radical is contained. The simplest formula that can be constructed is probably—

$$\left.\begin{array}{l} C_{40}\,H_{84}\,N_2\,P\,O_8\,Cd\,Cl_2 \\ C_{40}\,H_{83}\,N\;\;P\,O_8\,Cd\,Cl_2 \\ C_{40}\,H_{84}\,N_2\,P\,O_8\,Cd\,Cl_2 \end{array}\right\}$$

Paramyeline Cadmic-Chloride, $C_{38}\,H_{75}\,N\,P\,O_9$, $Cd\,Cl_2$, and its hydrate, $C_{38}\,H_{77}\,N\,P\,O_{10}$, $Cd\,Cl_2$, *from ox buttery after kephaloidine.* When the buttery matter dissolved in ether had been precipitated by alcohol and the kephaloidine been removed, the mother liquor on standing deposited some secondary kephaloidine and cholesterine. These were filtered off, the liquid precipitated with $Cd\,Cl_2$; the precipitate was washed with alcohol and pressed; it was next extracted with ether (which dissolved a small quantity of kephaloidine $Cd\,Cl_2$) until pure, dried, and analysed. The result of the analyses showed, that the body was a $Cd\,Cl_2$ compound, but there was no easy rationality between the elements of the organic molecule. The latter amounts to 77·49 °/₀ the $Cd\,Cl_2$ to 22·51 °/₀.

Treatment with Benzole.—It was found that the compound was entirely soluble in boiling benzole, and deposited a portion on cooling which was white and voluminous. Another portion remained dissolved in the cold benzole. The deposit was isolated by filtration, dissolved once more in boiling benzole, and was deposited as a swelled gelatinous mass; this was drained from benzole by blotting paper and dried. (Preparation 1235). The benzole solution which deposited nothing on standing in the cold was concentrated by distillation, and then precipitated by absolute alcohol, the precipitate washed and dried. (Preparation 1236.)

(*a.*) *Paramyeline Cadmic-Chloride.* — $C_{38}\,H_{75}\,N\,P\,O_9$, $Cd\,Cl_2$, insoluble in cold benzole.

Analyses.—The analyses were carried out in the usual manner, but the Cd was disregarded, as the fusion method is not reliable with this element.

(1.) 1·1505 grm. dried at 80° gave,—

(*a.*) 0·384 grm. $Ag\,Cl$ = 8·255 °/₀ Cl, [to this a quantity of 13·02 °/₀ Cd. would correspond.]

(*b.*) 0·1400 grm. $Mg_2\,P_2\,O_7$, equal to 3·396 °/₀ P.

(2.) 0·441 grm. gave 0·7970 grm. CO_2=49·288 °/$_o$ C and 0·3294 grm. H_2O = 8·299 °/$_o$ H.

(3.) 0·5321 grm. gave 7·7 c.c. gas at 22° C and 765 m.m. B.; KHO column = 16·4 m.m. Hg, gas = 6·8 c.c. normal = 1·598 °/$_o$ N.

Summary:—

	C	49·288	78·725
	H	8·299	
	N	1·598	
	P	3·396	
Hypothetical	O	(16·144)	
	Cd	(13·020)	21·275
	Cl	8·255	
		100·000	100·000

Computation of Organic Molecule:—

	Per cent.	÷by At wts.	÷by P=1.
C	62·607	5·217	37·5
H	10·541	10·541	75·8
N	2·029	0·144	1·0
P	4·313	0·139	1·0
O	20·510	1·281	9·2
	100·000		

The formula $C_{38}H_{75}NPO_9$ gives an atomic weight of 720, but the atomic weight calculated from the $CdCl_2$ is only 677. There is therefore still an irrationality between the chloride and the organic molecule, in the sense of the metallic salt being in excess.

Paramyeline Hydrate Cadmic-Chloride.—$C_{38}H_{77}NPO_{10}$, $CdCl_2$. (C_{37} ?) (Prep. 1236). Soluble in cold benzole.

Analyses.—All preparations dried at 80°.

(1.) 0·5000 grm. gave 0·8310 grm. CO_2 = 45·237°/$_o$ C; and 0·3570 grm. H_2O = 7·933°/$_o$ H.

(2.) 0·420 grm. gave 6·2 c.c. gas at 26 c. and 764 m.m. B.; KHO= 16 m.m. Hg; equal to 5·38 c.c. gas normal = 1·602°/$_o$ N.

(3.) 0·9380 grm. gave 0·3660 grm. AgCl = 9·652°/$_o$ Cl (to this quantity would correspond 15·222°/$_o$ Cd); further, 0·112 $Mg_2P_2O_7$ = 3·334°/$_o$ P.

Summary:—

C	45·327	75·126
H	7·933	
N	1·602	
P	3·334	
O	(16·930)	
Cd	(15·222)	24·874
Cl	9·652	
	100·000	100·000

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Computation of Organic Molecule :—

	Per cents.	÷ by At. Wgts.	÷ by P = 1.
C	60·334	5·028	$C_{36\cdot9}$
H	10·559	10·559	$H_{77\cdot6}$
N	2·132	0·152	$N_{1\cdot1}$
P	4·437	0·136	P_1
O	22·538	1·408	$O_{10\cdot3}$
	100·000		

Nearest formula $C_{37}H_{77}NPO_{10}$, more probably $C_{38}H_{77}NPO_{10}$, with atomic weight 738; the $CdCl_2$ is greatly in excess of the molecule, and leads only to 552 atomic weight.

Diagnosis.

The solubility of this paramyeline in ether distinguishes it from myeline, which is only little soluble in ether; its solubility in ether alcohol separates it from the kephaline group, from which it also differs by the insolubility of its cadmium compound in ether; it thus approximates by its solubilities most to the group of the lecithines, to which it also shows analogies by its bearing during chemolysis. But it differs from the lecithines *by its platinic chloride salt being insoluble in ether*, as was ascertained by the following experiment:—

Attempt to transform the foregoing $CdCl_2$ salt into $PtCl_4$ salt.—A quantity of 10 grm. of the analysed bodies was triturated very finely, first by itself, and then with H Cl, diluted with an equal volume of water, and then allowed to stand for about three hours. It was next thrown on a filter and washed with water; when the excess of H Cl and $CdCl_2$ had been washed away, the substance became mucilaginous and filtration ceased. The liquid in the funnel was poured off, and the soft yellowish white matter treated with cold absolute alcohol. This left a flaky white matter undissolved, which, however, dissolved in hot absolute alcohol, and was deposited on cooling in minute white granules, the alcohol remaining saturated with it, so as to give a precipitate with $PtCl_4$, and leave a matter on evaporation. The first cold alcohol solution was precipitated completely with $PtCl_4$, and the yellow precipitate isolated, treated with ether, *which extracted nothing*, and dried in vacuo. It weighed only 2·13 grm., and on analysis was found to contain 80·45% of organic matter, and 19·55% of $PtCl_6$, so that it was evidently formed upon the type of the platino-chlorides-hydrochlorates: viz., 2 paramyeline + 2 H Cl + $PtCl_4$, with a slight excess of H Cl over that required by $PtCl_6$, and also a slight excess of organic matter, so common in the compounds of the kephaline series, and explained by the chemolytic action of water. On the whole, this method of transformation is unsatisfactory, and does not deserve to be repeated, particularly on account of the small yield.

Cannot be washed with water.

Chemolysis of the foregoing salts by BaH_2O_2. 10 grm. were boiled with concentrated caustic baryta, containing excess of crystals, for one hour. Solution and precipitate were little coloured; they were separated by filtration.

The precipitate was washed and decomposed with cold H Cl. The insoluble part was washed to near freedom from H Cl, and then dissolved in hot absolute alcohol. Immediately on cooling a *first crystalline deposit* formed, which was filtered off. The solution evaporated to one half deposited, over night, white zeolithic masses of *light crystals*, being a *fatty acid*. The solution further evaporated deposited a *crystalline coloured fat* fluid while hot, nearly solid on cooling. These products will be described lower down as *first*, *second*, and *third acids*.

First crystalline deposit.

Second and third deposit.

The barytic solution was treated with excess of CO_2, and heat, filtered, concentrated, and precipitated with Pb acetate. The precipitated *Pb glycerophosphate* was removed; the excess of lead precipitated by H_2S, the solution filtered, evaporated to dryness, treated with a few drops of HCl to expel acetic acid; the residue dissolved in water, and filtered from a small quantity of *green base;* mixed with $PtCl_4$ and absolute alcohol, which precipitated *choline* and *neurine* $Pt\,Cl_4$, mixed with some $BaCl_2$. The Ba was cautiously removed by H_2SO_4, and the crystals obtained pure.

The solution.
Pb glycero-phosphate.
$PtCl_4$ salts.

First Crystalline Deposit.—This having been deposited immediately on cooling, was filtered off, washed with cold absolute alcohol, pressed between paper, and represented white microscopic crystalline needles, much resembling the needles obtained from cerebrine by the action of HCl or H_2SO_4. They soften at 75°, at 84° bubble and blister from loss of fluid (either water or alcohol), and then set dry. The mass does not fuse at 95°, at 105° maintains its shape, but is soft like wax when kneaded between the fingers. At 120° it is transparent, and nearly fused. At 127° it is a colourless, transparent oil, but very viscid, and not mobile. On cooling it becomes hard, and remains translucent, like milky glass or porcelain, and is not crystalline, but brittle. This body has not yet been any further examined. The crystals, pressed between paper and dried in air, when boiled with absolute alcohol, dissolve in great part, but leave a *fused* or *stearoconotised* portion undissolved behind; this adheres to the glass, and remains insoluble on boiling with much alcohol; after removal of the alcohol it cracks, but remains adherent to the glass. The alcoholic solution gives copious white precipitate with Pb acetate. Myeline behaves in a similar manner. On the other hand none of the known fatty acids observe such conduct, and they are therefore excluded from consideration.

The Second Deposit, or Crystals of Fatty Acid.—This crystallised from the absolute alcohol solution after concentration to one half on standing over night. It was very different from the first, being in dense balls of zeolithic needles, and breaking up on pressure, much like margaric acid so called. It was filtered off, washed with some absolute alcohol, and pressed between bibulous paper, dried in air. White; softens at 49°, fuses at 50°, entirely liquid at 54°. Solidifies crystalline at 50° to 51°, thermometer immersed. (These fusing points correspond to myristic acid, containing a little lauric, but the analyses to be related do not confirm this hypothesis.)

Second deposit.

The acid was dissolved in a small quantity of warm absolute alcohol, and precipitated by baric acetate solution; the precipitate was filtered, and washed three times with absolute alcohol, and when dry weighed 0·5272 grm.

Analyses.—(1.) 0·1166 grm., dried at 70° C., and ignited with H_2SO_4 and HNO_3 alternately, until white gave 0·0404 grm. $BaSO_4$ = 20·37 °/$_o$ Ba.

(2.) 0·2053 grm., dried at 80°, burned with chromate, gave 0·4294 grm. CO_2 = 57·042 °/$_o$ C, and 0·1824 grm. H_2O = 9·871 °/$_o$ H.

Summary of Analyses:—

	°/$_o$	÷ by At. Wgts.	÷ by Ba = 1.
C	57·042	4·753	31·98
H	9·871	9·871	66·42
O	12·72	0·795	5·35
Ba	20·37	0·1486	1·00
	100·000		

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leading to 2 ($C_{16} H_{31} O_2$) Ba, $H_2 O$, therefore a salt very nearly isomeric with palmitate or margarate. These few tests exhausted the material.

Third deposit. Third acids.

The Third Deposit.—The solution filtered from second deposit was evaporated until an oil collected on its top, and allowed to cool. The oil became semisolid. The fatty matter was filtered off, washed with water, and dissolved in watery ammonia. It formed a turbid, slimy solution, which, after heating with more water, could be filtered. To the solution Pb acetate was added, the curdy precipitate filtered off, washed with water, and dried over $H_2 S O_4$. It was next extracted with ether, and residue dried and weighed = 2·57 grm. The ethereal yellow extract was distilled to dryness from a previously weighed flask, and found = 2·7175 grm. The exact study of these products requires much larger quantities of material than were at my disposal.

Glycero-phosphate of Pb.

The Glycerophosphate of Lead was filtered and washed, and boiled twice with large quantities of water, and washed on a new filter with hot water. The white salt was dried over $H_2 S O_4$; it shrank very much to a horny coloured mass, and weighed when dry 1·5 grm. Of this 1·409 grm. were burned, and left 1·097 grm. $Pb_2 P_2 O_7$; it was consequently pure glycerophosphate, which should leave 1·098 grm. pyrophosphate.

Basic body.

The Green Basic Body.—When all acid was driven off from the choline-neurine hydrochlorate, after removal of Pt by $H_2 S$, and the residue dissolved in water, a greenish body remained undissolved, which from the mode in which it was obtained may be considered as the hydrochlorate of a base. Insoluble in water, it dissolved easily in absolute alcohol, forming a dark red solution. In this $Pt Cl_4$ produced neither precipitate nor change. (The solution was lost, but it is known from other experiments that the $Pt Cl_4$ compound is precipitated by ether from its alcohol solution.)

Choline and neurine salt.

The Choline and *Neurine Pt* Cl_4 was filtered, and washed with absolute alcohol, dried in air, and redissolved in a minimum of water, filtered from a slight yellowish, grey, insoluble deposit. As it did yet contain $Ba Cl_2$, it was again transformed into simple chloride by removal of the Pt by $H_2 S$, and evaporation. The residue was extracted with absolute alcohol in small quantities, as long as the extracts gave any precipitate with $Pt Cl_4$. $Ba Cl_2$ in white crystals was left behind. To the united extracts $Pt Cl_4$ was added as long as any precipitate ensued, excess of $Pt Cl_4$ being avoided. The precipitate, yellow and powdery at first, became orange brownish during drying, and assumed a more dense and crystalline state. It weighed 1·6 grm. air-dry, equal to 0·532 grm. choline and neurine. This corresponds to only 3·35 grm. of the body taken for chemolysis, and even if the larger formulæ were to prevail for this compound, the choline-neurine obtained would not represent half the nitrogen contained in the original $Cd Cl_2$ salt.

Computation of the Quantities of Products obtained in this Chemolysis.

$Cd Cl_2$ to be deducted - - - -	2·251 grm.
First crystals from alcohol (estimated) - -	1·000 „
Second crystals, fatty acid (Ba salt=0·5272 grm.) -	0·400 „
Assumed oleic acid (from 2·7175 grm.) of Pb salt -	1·993 „
Assumed margaric acid (from 2·57 grm.) of Pb salt -	1·834 „
Glycerophosphoric acid (from 1·5 grm. Pb salt -	0·684 „
Choline and neurine (from 1·6 grm. $Pt Cl_4$ salt) -	0·532 „
Loss in operations, green base, &c. - - -	1·306 „
Total - -	10·000 „

Myeline-Cadmic-Chloride.—$C_{84} H_{166} N_3 P_2 O_{18} + 2 Cd Cl_2$ from ox, white matter. This preparation constitutes the largest bulk of the compounds of the myeline class obtained in this research. It contains the myeline which is the least soluble, as is shown by the mode in which it was obtained. The white matter, from which cold absolute alcohol had extracted the more soluble compounds:—from which ether had extracted the kephaline and cholesterine, and which then appeared to consist mainly of bodies of the cerebrine series, was found to contain much phosphorus. It was finely powdered and boiled with absolute alcohol, the solution was decanted from the stearoconote, and some kephaline, filtered hot, and allowed to stand. Three successive deposits were separated, which will be described under the record relating to the cerebrine, phrenosine, and kerasine series. The alcoholic filtrate on standing several days in stoppered bottles deposited some kerasine in the form of gelatinous granules and membranes consisting of microscopic waves of needles. The alcoholic filtrate from this was saturated with a body, which gave a copious white precipitate with $Cd Cl_2$. It was necessary to combine the whole with this salt, in order to remove cholesterine, of which there was also much contained in the fluid, as shown by ultimate concentration of the mother liquor. The copious precipitate was washed with absolute alcohol, then suspended in and exhausted with ether, and dried, first in the open air, then under the air pump, with the aid of sulphuric acid. This process of drying lasted many weeks, as the alcohol and ether clung pertinaceously to the substance. It had to be powdered many times, and the sulphuric acid used for drying had to be frequently renewed before the substance appeared dry. The half dried substance when heated in a water bath to 90° C. became a transparent, viscous, soft mass; on cooling this became again hard and pulverizable, it was thus powdered and again exposed to 80° C., when it again became soft, but less so than at first; cooled and ground in mortar a second time it now retained its pulverulent nature on heating and did not fuse or become soft. From this it is probable that water, and alcohol, and ether were strongly combined with this body, and that the observed fusion was really a kind of solution in a small portion of these agents. The portions used for the following analyses were then dried, and subsequently at 70° C. till their weight was constant.

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Large preparation.

How obtained.

Mode of drying.

Analyses.—(1) 1·0233 grm. fused as above described gave 0·1230 $Cd O = 10·983$ °/ₒ Cd; 0·3050 $Ag Cl = 7·373$ °/ₒ Cl; and 0·118 $Mg_2 P_2 O_7 = 3·220$ °/ₒ P.

(The 10·983 °/ₒ Cd require 6·961 °/ₒ Cl. The 7·373 °/ₒ Cl require 11·630 °/ₒ Cd, so that the Cd is deficient to the extent of 0·647 °/ₒ, the result probably of volatisation during fusion.)

(2.) 0·4466 grm. burned with chromate gave 0·8570 grm. $C O_2 =$ 52·234 °/ₒ C, and 0·346 grm. $H_2 O = 8·607$ °/ₒ H.

(3.) 0·5424 grm. gave 11c.c. gas at 19° C. and 753 m.m. B.; KHO column = 17 m.m. Hg, equal to 9·74c.c. gas normal = 2·246 °/ₒ N.

Summary of results:—

C	52·334	81·644
H	8·607	
N	2·246	
P	3·220	
O	15·237	
Cd	10·983	18·356
Cl	7·373	
	100·000	100·000

Computation of free Molecule :—

	Per cents.	÷by At. Wts.	÷by P=1
C	64·100	5·341	42·05
H	10·542	10·542	83·00
N	2·750	0·196	1·54
P	3·943	0·127	1·00
O	18·665	1·166	9·18
	100·000		

Theory of Atoms :—

42	C	504	783
83	H	83	
$1\frac{1}{2}$	N	21	
1	P	31	
9	O	144	
1	Cd	112	183
2	Cl	71	
		966	966

Of course the theory with P = 1 is inadmissible on account of the N, which compels us to double the empirical formula to $C_{84}H_{166}N_3P_2O_{18}$, $+2\ CdCl_2$. Taking Cl as found, and Cd equivalent to it (allowing a slight loss) leads to 963 as at. w. of compound, which is almost identical with theory from free body. Consequently, we have :—

$$\begin{aligned} Cl : P &= 2 : 1 \text{ or better} = 4 : 2 \\ Cl : N &= 2 : 1\tfrac{1}{2} \text{ ,, } \quad \text{ ,, } = 4 : 3 \end{aligned}$$

It is therefore possible or necessary to assume that we have here a mixture or compound in atomic proportions of two bodies, one of which contains only one atom of N, while the other contains two, thus :—

$$\left.\begin{array}{l} C_{42}H_{83}N\,PO_9 + Cd\,Cl_2 \\ C_{42}H_{82}N_2PO_9 + Cd\,Cl_2 \end{array}\right\} = C_{84}H_{165}N_3P_2O_{18} + 2\ Cd\,Cl_2$$

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c. *Sub-group of Lecithines.*

Explanation: Lecithine virtually found, not actually isolated.

In the chapter containing the description of the method pursued for the isolation of immediate principles, I have repeatedly stated that lecithine had been found, but have accompanied the statement by a query, as indicating that there was yet some doubt on the subject. This may be at once explained by the statement that the lecithine, when isolated in the only form in which it can at present be separated from the other brain matters, namely, as platinic chloride hydrochlorate salt, immediately after isolation began to decompose, and completed this decomposition during the steps necessary for its purification. The yellow salt, precipitated from ether by alcohol, when placed in the vacuum over sulphuric acid, became covered with oily drops (oleic acid), and the remaining yellow salt entirely lost its solubility in ether. On analysis of this insoluble part it was found to correspond to the probable composition of a plati-

Lecithine, how and when decomposed.

Pt salt lecithine minus oleyl.

num salt of a body having the composition of lecithine minus an atom of oleyl. But slight irregularities made it probable that a small part decomposes further, and leaves a platinum salt, free from fatty acid radicles, yet containing the radicles of glycerophosphoric acid and choline in combination. These circumstances produced conditions of such complication, that the time and opportunity was not sufficient for disentanglement, and the presence of lecithine in the brain is therefore not considered as proved, but only as probable.

Decomposition observed by others.

The decomposibility of lecithine from eggs has already been pointed out by Strecker; the ether solution of the platinic chloride salt he found to deposit crystals of choline platinic chloride on standing. This decomposibility was also no doubt the main cause of Gobley's non-success in his attempts at its isolation. I find that it decomposes rapidly on standing in absolute alcohol by itself; the liberated margaric and oleic acids in the nascent state form ethylic ethers, which settle as a heavy oil to the bottom of the vessel containing the solution. This oil then forms a material of almost inextricable confusion and complication, and has no doubt been the main cause of the frequent failures of attempts at brain analysis. When freed from all matters which can be precipitated by platinic chloride, cadmic chloride and lead acetate, applied in succession with all precautions, and when liberated from all alcohol it is a viscid oil, which partly crystallises at low temperatures, and at lower ones congeals entirely. When heated it does not observe the bearing of either the phosphorised bodies, or fats or fatty acids, but boils at a temperature near that of boiling mercury, and distils freely above 360° C., yielding an oily distillate in which crystals form on standing. This distillate is the pyrokephole of the alphabetical list; the original oil, unpurified, is the main ingredient of Couerbe's éléencephol, of the last oily of this research. During the early operations of brain-extraction the decomposition of lecithine is but slight, and the formation of the ethers insignificant. It begins to become more copious after concentration of the absolute alcohol extracts from white and buttery matter, by distillation of the absolute alcohol. It is accelerated by the treatment with platinic chloride and hydrochloric acid, but a large quantity of soluble in ether platinum salt is nevertheless obtained. The final decomposition is accelerated by the necessary separation of kephaline, which involves treatment with hydrothion in ether solution, and precipitation with absolute alcohol, when kephaline remains with the platinic sulphide, while lecithine as hydrochlorate with much hydrochloric acid remains in the alcohol solution. The hydrochloric acid has now to be removed by silver oxyde, the excess of the latter by hydrothion; the excess of hydrothion by carbonic acid and slight warming. In this solution platinic chloride produces a good precipitate of lecithine salt, of which most is yet soluble in ether. But after precipitation by alcohol and placing in the drier, the long course of severe chemical influences is, as it were, completed, and the shaken constitution of the lecithine succumbs to the influence of time and liberated hydrochloric acid.

Oily bodies formed, ethylic ether of fatty acids.

Distillate = pyrokephole.

Progress of decomposition of lecithine during manipulation.

We may therefore say that lecithine has virtually, though not actually, been isolated from the brain. It has yielded all the products of decomposition described by Strecker, and also the compounds, and has observed the bearing of a compound in a state of tension, or easy decomposibility. I have no doubt that means will be found for its isolation in its integrity. Perhaps the above process followed by me, if carried out with the greatest despatch by working it during night and day without intermission, would lead to the desired result. For the decomposition no doubt requires time as an essential element. But other processes are perhaps preferable. Thus if all phosphorised matters were precipitated from the first extrac

Processes of isolation of lecithine to be adopted in the future.

of white matter, or buttery matter by cadmic chloride; the precipitate freed from kephaline compound by ether; the remaining mixture of myeline and lecithine cadmic chloride salt freed from cadmic chloride by water and dialysis; and the mixture of myeline and lecithine separated first by a little ether, which would leave most myeline insoluble, but dissolve all lecithine; if now to this solution ethereal solution of platinic chloride were added, all myeline would fall, and all lecithine remain in solution. This could now be precipitated by alcohol, and the precipitate analysed; or the precipitate could be freed from platinum and hydrochloric acid as above described, and the solution evaporated. The compound of lecithine with lead is very soluble in alcohol, even of inferior strength, while the compound of myeline with lead is quite insoluble even in boiling alcohol. Perhaps this different behaviour may be used for their separation after they are isolated from other phosphorised matters and cholesterine by the cadmic chloride and ether treatment.

B.—Group of Nitrogenised Principles.

(*a.*) *Sub-Group of the Cerebrines.*

CONTENTS.

General Peculiarities of the Group.

In the classification I have given cerebrine and its several varieties as the first term of the group of principles containing four elements, C, H, N, and O, termed the nitrogenised group of immediate principles of the brain. I have shown in the historical appendix that the term cerebrine was first used by Kühn, and later by Lassaigne, for ill-defined products of their operations; later by Gobley to signify what was no doubt mainly a mixture of bodies belonging to this group, with some myeline, but the representative body of this group, the cerebrine $C_{17} H_{33} N O_3$ (or $C_{34} H_{66} N_2 O_6$) was first discovered by Müller, and well characterised by its freedom from phosphorus, and the relatively large amount of nitrogen which enters into its composition. By the present research it is now found to be apparently the lowest representative of a group of immediate principles of the brain which are free from phosphorus, contain nitrogen, and vary in the number of carbon atoms, which they contain for each nitrogen atom between 17 and 48. Whatever may be the ultimate explanation of these differences of composition must be left for future inquiry. Meanwhile it is certain that these differences do but slightly affect the external appearance and bearing towards solvents of these

bodies, so that by describing the general properties of one we describe the general properties of all members of the group, while differentiating characters and means are most difficult of discovery and application.

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On the Chemical Constitution of the Brain, by Dr. Thudichum.

General characters of cerebrines.

They are all white, like snow, but are capable of becoming in part transparent, like wax. They are deposited from hot alcoholic solutions in minute balls of still more minute, *i.e.*, microscopic particles, which may be termed crystalline, but have no claim to be termed crystallised. [The balls of myeline are very similar in appearance, but their elements are much more distinctly crystallised than those of the cerebrines.]

Soluble in alcohol.

The cerebrines are all soluble in hot alcohol, particularly absolute alcohol, and deposited on cooling; they are very little soluble in cold absolute alcohol, much less soluble indeed than myeline, which can thus be separated from the cerebrines. The mixture is dissolved in hot alcohol and allowed to cool; nearly all cerebrine falls down, much myeline remains in solution. The deposit is separated from the liquid and subjected to this treatment until it is free from phosphorus.

Solubility in water.

Solubility in Water.—The cerebrines are almost insoluble in water, though they swell with it, particularly on boiling. One grm. of purified cerebrine (from ox, third portion of Nr 2 of my preparation list) was powdered and boiled in 100 c.c. of water, filtered through force filter, and 50 c.c. of the filtrate were evaporated on the water bath to dryness in a platinum dish, which increased in weight by 0·025 grm. Consequently one part of this cerebrine was soluble in 2,000 parts of water.

Bearing with benzole.

The cerebrines are quite insoluble in cold benzole. Thus a quantity (from ox, Nr 3) was shaken with benzole; it became swelled and quite transparent, so as to almost disappear from sight. The benzole was filtered off and evaporated, and did not leave a vestige of matter behind. But in hot benzole the cerebrines are extremely soluble, and on cooling are deposited as a gelatinous mass, which requires agitation before it can be filtered. From the hot solution cold alcohol precipitates white flakes. This treatment facilitates the separation of the cerebrine from the benzole.

Bearing with ether.

The cerebrines are almost insoluble in either cold or hot ether, and are by this solvent easily purified from kephaline and its relatives, from much myeline, and from lecithine, and also from cholesterine and fats. But the separation from myeline cannot be effected so easily by ether as by the absolute alcohol treatment above described.

Bearing with H^2S.

In order to ascertain the bearing of cerebrine under different circumstances with hydrothion, three experiments were made with cerebrine from man, Nos. 4 and 5. A quantity was suspended in ether and H_2S passed through the mixture. No change took place. A mixture of cerebrine with alcohol and some HCl also remained unaltered. A mixture of cerebrine with ether and alcoholic $CdCl_2$ formed a yellow precipitate. Cerebrine therefore behaves neutrally towards H_2S, unlike kephaline, which seems to combine with it, and then retains metallic sulphides in solution in ether.

Cerebrine and Phrenosine from Brain of Man.

Cerebrine No. 1.

Cerebrine (No. I.) $C_{17}H_{33}NO_4$ *from Brain of Man, by Baryta Process.*—This experiment was performed on two human brains (typhus) after the precedent of Müller. The organs, hardened in alcohol, were transformed into a pulp and boiled with baryta water; the solid residue

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was filtered off, and after washing exhausted with boiling alcohol. The latter deposited *cerebrine*, which was extracted with ether, recrystallised from alcohol, and analysed. Dried in hot water oven at about 90° C, the powder became slightly caked, but did not become coloured or show signs of decomposition.

Analyses.—(1.) 0·5744 grm. burned with lead chromate gave 1·3843 grm. CO_2 = 65·7°/₀ C, and 0·5610 grm. H_2O = 10·8°/₀ H.

(2.) 0·3609 grm. gave 13·9 c.c. of N at 11° C, and 760·69 B. potash column 240 m.m. = 12·7 c.c. N normal or 4·4°/₀ N.

Summary:—

	°/₀ found	÷ by N=1.
C -	65·7	17·1
H -	10·8	34·4
N -	4·4	1·
O -	19·1	3·8
	100·0	

leading to $C_{17}H_{33}NO_4$, or $C_{17}H_{33}NO_3H_2O$. This is the only time that I have obtained this cerebrine; all other preparations, even by the same process, contained much less nitrogen, or assuming nitrogen as 1 as the term of comparison many more atoms of C, H, and O than this. It differs from Müller's cerebrine only by containing nearly an atom of H_2O more than this.]

Man, No. II.

Phrenosine (No. II.) ($C_{35}H_{69}NO_8$).—This was also obtained by baryta process in exactly the same manner as No. 1, but was found to contain only half the amount of nitrogen, or it contained, in addition to $C_{17}H_{33}NO_4$ the complex $C_{18}H_{36}O_4$, which is not unlike Koehler's myelomargarine or Otto's cerebrine, both said to be free from N. But I have never found any substance of the cerebrine group to be free from nitrogen, and am rather inclined to assume that the true molecular formula of cerebrine No. 1 is $C_{34}H_{69}N_2O_8$, and therefore may be considered as the diamido form of the radical of which phrenosine is the mono-amidated form.

Analyses.—(1.) 0·3188 grm. gave 0·7734 grm. CO_2 = 66·1°/₀ C, and 0·3180 grm. H_2O = 11·0°/₀ H.

(2.) 0·3729 grm. gave 7·5 c.c. N at 15° 5 C.; H K O column 252 m.m. Bar. = 756·1 m.m. = 6·7 c.c. normal or 2·2°/₀ N.

	°/₀ found.	÷ by N = 1.
C -	66·1	35·1
H -	11·0	70·6
N -	2·2	1·
O -	20·7	8·1
	100·0	

leading to $C_{35}H_{69}NO_8$. I preserve this and all other cerebrines not produced from promiscuous materials for future study, particularly in the hope of meeting with preparations of similar empirical composition with which they might be united.

From the foregoing phrenosine ether extracted, previous to analysis, a

body which after distillation of the ether remained as a gelatinous cheesy cake, drying up to a thin film, probably myeline.

Cerebrine No. III.

Cerebrine and Phrenosine (III.) ($C_{24} H_{47} N O_5$). This body was obtained without the intervention of baryta. The brain pulp was simply boiled with alcohol, the extract filtered, and allowed to cool; the deposit was filtered off. On attempting to redissolve this in boiling alcohol a portion fused together: the mass was therefore powdered again and extracted with much alcohol at 45°. The insoluble portion proved to be stearoconote (Couerbe), soluble in benzole and reprecipitated by alcohol. The cerebrine and phrenosine from the alcohol extracts, after extraction with ether, had composition :—

Analyses.—Dried about 90° C. (1.) 0·3486 grm. gave 0·8565 grm. $CO_2 = 67·01\%$ C; and 0·3471 grm. $H_2O = 11·06\%$ H.

(2.) 0·4836 grm. yielded 13·3 c.c. of gas at 19° C. K H O = 238 m.m.; Bar. = 752· m.m., equal to 12·3 c.c. gas normal = 3·19% N.

	% found.	÷ by N=1.	÷ by N=4.
C	67·01	24·6	98·
H	11·06	48·7	195·
N	3·19	1·	4·
O	18·74	5·1	20·
	100·00		

If we multiply these figures by × 4, and then deduct two molecules of $C_{17} H_{33} N O_4$, or one molecule of $C_{34} H_{67} N_2 O_8$, there remain about two molecules of $C_{34} H_{69} N O_8$. We can consider this body as being a mixture of :—

1 mol.	$C_{34} H_{67} N_2 O_8$	cerebrine.
2 mols.	$C_{34} H_{69} N O_8$ $C_{34} H_{69} N O_8$	phrenosine.
	$C_{102} H_{205} N_4 O_{24}$	(See cerebrine Nos. IV. and V.)
Found	$C_{98} H_{195} N_4 O_{20}$	

Man, cerebrine IV. and V.

Cerebrine and Phrenosine IV. and V. ($C_{25} H_{51} N O_6$.) This was extracted from the brains by alcohol at 45° C; it was next extracted by cold alcohol, then cold ether, recrystallised from alcohol, and washed with ether.

Analyses (1.) 0·3914 grm. (dried below 90° C, at which temperature it became coloured), gave 0·9388 grm. $CO_2 = 65·41\%$ C, and 0·3862 grm. H_2O, equal to 10·96% H.

(2.) 0·3923 grm. yielded 10·8 c.c. gas at 19° C, and 752 m.m., which, corrected, was equal to 3·0% N.

	% found.	÷ by N = 1.	N = 4.
C	65·41	25·4	101·6
H	10·96	51·2	204·8
N	3·00	1·	4·
O	20·63	6·	24·
	100·00		

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The hypothesis which I applied to Cerebrine III. fits the present preparation even much better.

Required - - C_{102} H_{205} N_4 O_{24}
Found - - $C_{101 \cdot 6}$ $H_{204 \cdot 8}$ N_4 O_{24}

These figures are in effect identical, and their harmony strongly supports the hypothesis.

Cerebrine and Phrenosine, VI., VII., VIII.

Cerebrine and Phrenosine VI., VII., and VIII. was prepared like the foregoing, and analysed.

(1.) 0·2837 grm. gave 0·6903 grm. CO_2 = 66·35 °/$_o$ C, and 0·2814 H_2O = 11·01°/$_o$ H.

(2.) 0·4860 grm. gave 10·7 c.c. gas at 20° C, and 763 m.m. B, K H O 275 m.m. = 9·45 normal, or 2·43 °/$_o$ N.

	°/$_o$ found.	÷ by N = 1.	× 17 N.
C	66·35	÷ 31·9	542·3
H	11·01	63·6	1081·2
N	2·43	1·	17·
O	20·21	7·3	124·1
	100·00		

Applying to this body the foregoing hypothesis, I find that it may be considered as a mixture of 15 molecules of phrenosine, $C_{34}H_{67}NO_8$, with one molecule of cerebrine, $C_{34}H_{67}N_2O_8$, which requires $C_{544}H_{1072}N_{17}O_{128}$, while $C_{542 \cdot 3}H_{1081 \cdot 2}N_{17}O_{124 \cdot 1}$ are found, figures which again show a surprising degree of harmony, considering the very large numbers of atoms involved in the calculation.

It is thus shown that different human brains yield immediate principles of the cerebrine series, which apparently greatly differ in elementary composition, though they are very similar in chemical reaction; but, by a simple hypothesis, they are reducible to two primary forms, mixed in varying proportions—

Mono-amidated form - $C_{34}H_{67}N\ O_8$ phrenosine
Diamidated form - $C_{34}H_{68}N_2O_8$ cerebrine.

That the mono-amidated form really exists will be shown immediately; but there are reasons for assuming the existence of more complicated forms in mixtures, in which, besides the foregoing forms, bodies such as $C_{51}H_{101}NO_{12}$
$C_{51}H_{100}N_2O_{12}$
$C_{51}H_{101}N_3O_{12}$

may be engaged, or even an hypothesis dealing with these latter bodies, may in some instances take the place of the more simple hypothesis.

b. Sub-Group of Phrenosines.

CONTENTS.

Ox cerebrine.

Recrystallisation and Separation by Lead Treatment of the Cerebrine Group of Immediate Principles from Ox-brain.—The white matter, completely exhausted with ether and cold alcohol, was repeatedly recrystallised from alcohol, of 85 °/₀, and the stearoconotes were separated. When the precipitate dissolved freely and entirely in new alcohol, the solution was treated with a hot alcoholic solution of lead acetate, and a little ammonia. [The precipitated lead compound, which I will term *lead cerebrinate*, was washed, decomposed in hot alcohol by H_2S, filtered hot from PbS. The solution, on cooling deposited *cerebrinic acid*, which was filtered off and washed. It was by recrystallisation obtained in three portions, which will be treated of on a future occasion.] The alcoholic solution from which the Pb precipitate had been removed, and which contained all matters not precipitated by lead under the circumstances, besides some Pb acetate and NH_3 acetate, on cooling, deposited white *phrenosine*, which was filtered off and washed. It was next recrystallised from alcohol of 83 °/₀, during which some secondary lead salt became insoluble, and was removed. The phrenosine was again dissolved in hot alcohol, and a trace of lead removed by H_2S. On cooling, phrenosine and a solution were obtained which were again separated by the filter. The phrenosine was recrystallised from absolute alcohol, and yielded, on cooling, *purest phrenosine, part* 1, which was dried. The mother liquor of this was distilled to one-sixth, and, on cooling, deposited *purest phrenosine, part* 2. The rest of the liquid evaporated left *purest phrenosine, part* 3.

Pb cerebrinate and cerebrinic acid.

Purest Phrenosine, Part 1.—This was dried for days over H_2SO_4 in air pump, and finally, the portions used for analysis were dried at 65° C.

(1.) 0·5218 grm. gave 1·2743 grm. CO_2 = 66·60 °/₀ C. and 0·5260 H_2O = 11·20 °/₀ H.

(2.) 0·5260 grm. gave 10·75 c.c. gas at 18° C, and 772 m.m. B. KHO column = 173 m.m. = 20 m.m. Hg, equal to 2·30 °/₀ N.

	°/₀ found.	÷ by At. Wgts.	÷ by N = 1.
C	66·60	5·55	33·84
H	11·20	11·20	68·29
N	2·30	·164	1·
O	19·90	1·25	7·62
	100·00		

leading to formula $C_{34}\,H_{67}\,N\,O_8$.

Theory		
Of Atoms.		Per Cents.
34 C	408	66·12
67 H	67	10·85
1 N	14	2·26
8 O	128	20·74
	617	

Nitrited Phrenosine.—$C_{34}\,H_{66}\,(N\,O_2)\,N\,O_8 + H_2\,O$, 10 grms. of the substance just analysed were finely powdered, and added little by little to about 300 c.c. pure $H\,N\,O_3$, time being allowed for each portion to assume a gelatinous swelled condition before a new one was added. After all the phrenosine had been added, a thick paste resulted, with some tendency of separation of a solid towards the surface. No red fumes were given off during the operation. The bottle containing the mixture was placed in cold water during 14 hours, at the end of which time the air space in it had become filled with fumes of nitric peroxyde. The bottle was filled up with water, when the oily or gelatinous product immediately assumed a hard waxy consistence; it was filtered, washed with much water, pressed, and dried under air pump. Though kept in the dark, it gradually assumed a strong reddish colour, became hard and brittle, and could easily be powdered. The powder was yellow. It was soluble in hot ether.

Analyses.—Substance dried in air pump, not by heat.

(1.) 0·3977 grm. gave 16·5 c.c. gas at 18° C. and 764 m.m. B. K H O = 21 m.m. Hg, equal to 14·8 c.c. normal = 4·65°/₀ N.

(2.) 0·4394 grm. gave 0·960 grm. $C\,O_2$ = 59·58 °/₀ C and 0·3927 grm. $H_2\,O$ = 9·93 °/₀ H.

	Found	Calculated for $C_{34}\,H_{66}\,N_2\,O_{11}$
C	59·58	60·17
H	9·93	9·58
N	4·65	4·12
O	25·84	25·49
	100·00	99·38

By the process of nitration the nitrogen has at least doubled, and the oxygen has greatly increased. The nearest hypothesis compatible with the analyses leads us to the conclusion that an atom of H has been substituted by $N\,O_2$, and an atom of oxygen been added besides, or an atom of water, so that we obtain either $C_{34}\,H_{66}\,(N\,O_2)\,N\,O_8 + O$, or $C_{34}\,H_{66}\,(N\,O_2)\,N\,O_8 + H_2\,O$. The unquestionable fact of the entrance into the molecule of phrenosine of a molecule of $N\,O_2$ enables us approximately to fix the molecular weight as that given; in any case it could only have to be doubled or trebled, but not otherwise much changed in its proportions.

Phrenosine and Bromine. Mono and Dibrominated Phrenosine.

Phrenosine of the formula $C_{34}H_{67}NO_8$, same preparation as in the previous experiment, when exposed to bromine vapours becomes yellow and combines. The product is soluble in ether and in hot alcohol, and more soluble in cold absolute alcohol than the pure phrenosine.

When phrenosine is thrown into ether containing some Br there is a slight evolution of heat, and the phrenosine is immediately and entirely dissolved. A red solution remains which is not made colourless by powdery phrenosine in excess. The ether solution evaporated leaves a yellow thick residue, which is entirely soluble in warm absolute alcohol, and from this deposited on spontaneous evaporation. The ether solution when boiled with water seems decomposed; the body becomes white and flaky, and H Br is evolved. The products of the brominating process, after purification, when deflagrated with nitre and caustic soda, yield much Br to reagents.

10 grm. of the above purest preparation (ox) were finely powdered and added little by little to about half a pint of ether, coloured with Br; a little Br was added as often as the solvent action upon the phrenosine became slower. Finally a brilliant solution was obtained. To this about an equal volume of water was added, whereby a gelatinous precipitate was produced. Caustic potash was next added and the mixture shaken till the colour of Br was destroyed and the solution was alkaline. After some repose the mixture consisted of three layers, the one uppermost being ethereal and clear, the second one containing the gelatinous body in suspension, and the third being a watery solution of K Br and excess of alkali. The ethereal layer was syphoned off, washed with water, and then allowed to evaporate spontaneously. A homogeneous white mass was left, which was dried under the air pump over H_2SO_4, light being excluded.

Analysis.—0·7205 grm. were fused with caustic soda and nitre, and dissolved in water; silver nitrate in excess was now added and then nitric acid in excess. The mixture was heated to boiling, and the Ag Br filtered and washed, and weighed 0·2400 grm. equal to 14·17 % Br.

A monobrominated phrenosine requires above 11 % of Br; a mixture of one molecule of monobrominated with one molecule of dibrominated phrenosine

$$\left.\begin{array}{l} C_{34}H_{65}Br_2NO_8 \\ C_{34}H_{66}BrNO_8 \end{array}\right\}$$

requires 16·3 % Br. The above product is therefore such a mixture, in which the monobrominated body prevails. The reaction with Br is thus shown not to be simple, but to yield at least three bodies; of these the gelatinous body has not yet been any further analysed, as its isolation and purification is a matter of extreme difficulty. Nevertheless, experiments with large quantities of material promise interesting results.

Phrenosine and Iodine.—An ethereal solution of iodine was not discoloured by powdery phrenosine (same preparation as used with Br), and the phrenosine did not dissolve. After six weeks' contact the ethereal solution was allowed to evaporate spontaneously and left no residue. Therefore, under these circumstances phrenosine and iodine do not react upon each other.

Phrenosine and Sulphuric Acid in Alcohol.—10 grms. of the preparation $C_{34}H_{67}NO_8$ were dissolved in ¾ litre of hot spirit of 85 %

and 8 c.c. of oil of vitriol added. The mixture was gently boiled for one hour and became coloured red. When allowed to cool it curdled immediately to a mass of fine microscopic crystals. These were removed, pressed, and dried, and are named hereafter: *first deposit.* The filtrate from this was evaporated and furnished *the second deposit*; and the filtrate from this, on much concentration, yielded *the third deposit.* The mother liquor was very acid, and contained much sulpho-vinic acid, as was proved by treatment with baryta, crystallisation, &c. It contained no body in solution which reduced alkaline copper-solution.

Analysis of first deposit:—(1.) 0·4690 grm. dried at 80° C gave 1·1142 grm. $C\,O_2$ = 64·791 °/₀ C, and 0·4676 grm. $H_2\,O$=11·077 grm. H.

(2.) 0·5466 grm. gave 8·6 c.c. gas at 0°C and 760 m.m. = 1·96 °/₀ N.

	In 100°.	÷ by At. Wts.	÷ by N = 1.
C	64·791	5·399	38·55
H	11·077	11·077	79·12
N	1·960	·140	1·00
O	22·172	1·385	9·89

leading to formula $C_{39}\,H_{79}\,N\,O_{10}$, a formula which approaches remarkably to some of the myelines, phosphorus deducted. Under the influence of heat the body behaved like the original phrenosine. It seemed to be more soluble in ether than the original phrenosine, and was better crystallised. The action of sulphuric acid therefore seems to be in the direction of the removal of the nitrogenous nucleus. But it is evidently very complicated, for while the first deposit was soluble only in hot alcohol, the third one was entirely soluble in cold absolute alcohol, while the second deposit observed an intermediate solubility. Several bodies are therefore produced, which, though they crystallise, can be separated only by operations on much larger quantities than were at my disposal.

Phrenosine and Sulphuric Acid in Water.—About 1 grm. of phrenosine was placed in cold water and boiled until diffused; 5 grm. of $H_2\,S\,O_4$ were now added, so that the whole solution was about 50 grm. The mixture was boiled. The phrenosine coagulated at first, and on continued boiling changed in appearance, contracted, and floated on the surface. The insoluble matter was collected on a filter and washed. (White product; it gave no reduction with cupric solution.) The solution was boiled with $Ba\,C\,O_3$ until neutral, filtered and evaporated to near dryness, and deposited a white scaly matter. It had no taste, and particularly no sweet taste, and was not syrupy. It reduced cupric oxyde, the suboxyde falling in yellow flakes, different from that produced by sugar; a secondary deposit settled on yellow suboxyde. It gave no reaction with iron chloride or gold chloride. Caustic potash and heat made the solution slightly coloured yellow, but not brown, and there was no smell of caramel, but on cooling a darkish precipitate occurred. This reaction also is evidently too complicated to be satisfactorily studied on small quantities.

Reducing body.

Phrenosine and Hydrochloric Acid.—About 1 grm. was placed in a flask with H Cl and heated; it frothed a good deal and formed a red solution, the phrenosine swelling greatly. The swelled mass isolated and washed with water was found for the most part soluble in cold absolute alcohol. This solution evaporated to a low bulk deposited in

the form of microscopic needles, which when dry fused about 100° C, and became brownish at 125°; on cooling they were like wax, evidently a body differing greatly from the original phrenosine. The hydrochloric acid solution, after neutralisation tested with Fehling's test, reduced the copper, but unlike sugar, the cuprous oxyde falling in flakes, as in the reaction with H_2SO_4. Possibly there are here two bodies of which one flaky causes the Cu_2O to assume the flaky shape.

Product reduces copper test.

Action of Heat upon this Phrenosine.—0·5290 grm. lost on drying between 18° and 70° C. 0·0084 hygroscopic water, and the remaining 0·5206 grm. were considered as dry substance. After two hours' exposure to a heat of 97° C. in a large air-bath it became slightly yellow, and had lost 0·0016 grm. After three hours' exposure to 101° it had remained of the same colour and weight. After two hours' exposure to 145° it had become very dark, almost black in colour, and superficially fused, and had lost 0·0080 grm. After heating to 158° during three hours it had become thoroughly fused, and of a reddish almost transparent aspect; it had lost 0·0120 grm. in weight. After four hours at 177° C. it had become blacker and less transparent, and gave out a faint odour of burnt meat; it had lost at this stage 0·0317 grm. Thus the phrenosine had lost in four stages 0·0533 grm., or 10·2 % in weight. Taking atomic weight of $C_{34}H_{67}NO_8$ as 617, this loss, considered as a loss of water only, amounts to 3·5 atoms H_2O very nearly. After cooling it was hard and brittle. On boiling a piece in absolute alcohol only a trifling amount of matter dissolved, colouring the solution slightly yellow. On the other hand, it readily dissolved in ether; the solution had a dark reddish brown colour.

A little of the same phrenosine was heated in a test tube over the naked flame. It fused, turned dark, and evolved water with ebullition, similar to sugar passing into caramel. The water which condensed in the upper part of the tube had an acid reaction and reduced copper solution. The fused matter became hard on cooling, was but slightly soluble in boiling alcohol, but readily soluble in ether; from the latter solution it was reprecipitated by alcohol.

Fusion over gas flame.

Phrenosine and Chromic Acid.—Trituration with an equal bulk of crystallised chromic acid produces a mass which, soft at first, and smelling of butyric acid, becomes soon solid, and afterwards can be powdered. Is easily soluble in cold absolute alcohol, and after standing in a beaker for a few days a gelatinous cake is formed. (Chromate of phrenosine?) This when heated gives out fumes, and then suddenly deflagrates, sometimes throwing particles about, leaving chromic oxyde. Boiled with water it forms a plastic mass on the water, which after washing is partially soluble in alcohol, partially in ether; another part is insoluble in both solvents, and consists of a compound of chromic oxyde with some organic matter.

Phrenosine dissolved in glacial acetic acid with the aid of a little heat, is easily attacked by crystallised chromic acid added to the solution. Much gas is evolved, the solution becomes green, and on cooling deposits some product in flakes. Water added to this solution produces a copious precipitate of dark green flakes.

Phrenosine and Alkaline Permanganate.—Phrenosine, boiled with alkaline permanganate, decolourises the latter; green at first, the liquid becomes brown with manganic oxyde. Flakes of decomposition products are formed, and the liquid remains turbid.

Phrenosine and Lead Peroxyde.—Phrenosine triturated with lead peroxyde produces no reaction; none on boiling with water or dilute H_2SO_4. H₃O.

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Ba H² O².
Pb acetate.

Reactions with Water, Alcohol, Caustic Baryta, Lead and Copper Acetate.—Boiled in *water* it swells, and forms, with the aid of agitation, a thick white paste. Baryta water added to this, while hot, forms an immediate curd, which can be filtered, but not washed, as water causes it to swell and filtration ceases, and the rest of the fluid becomes clear. Later, the white flocculent precipitate settles. In the watery solution lead acetate forms a thick curd, which contracts when the mixture is boiled, and is suspended on the top of the fluid or settles. This has smaller bulk than the baryta precipitate; it can be washed with cold or hot water for some time, during which it loses lead. In alcohol of 85 °/₀ phrenosine dissolves completely on heating. In this solution a few drops of baryta water cause an immediate white flaky precipitate. By a sufficient amount of baryta water, added if need be after filtration, a point is reached where baryta water ceases to produce a precipitate. The liquid on cooling sheds a precipitate, soluble on boiling, being a small portion only of the substance originally employed. Alcoholic lead acetate also causes an immediate copious white precipitate in the hot alcoholic solution, insoluble on boiling; another precipitate after filtration, until the acetate leaves the liquid clear. The filtrate deposits some white matter on cooling. [This reaction is very curious, considering the mode of preparation.] Boiled in water, and treated with cupric acetate, it yields a copious light blue coagulum. This remains bluish green during washing, and does not swell.

Alcohol Ba H² O².

Pb acetate.

Cu acetate.

Bearing of the Lead and Copper Compounds during Washing with Water.—By prolonged washing with cold water they always yielded clear solutions, which, with ammonium sulphide, gave a brownish colour, but no precipitate on standing. This showed that the compounds were a little soluble in water, and like the kephaline compounds coloured, but not decomposed by NH_4H_2S.

Pb salt.

A quantity of lead salt, prepared by acetate from phrenosine swelled in water, was washed for two days, the filtrates containing metal to the last.

0·5160 grm. dried at 100° (at which T. the salt was pasty) gave 0·0396 grm. $PbSO_4$ = 5·24 °/₀ Pb.

Cu salt.

A quantity of copper salt, prepared exactly like the lead salt, from 1 grm. of dry phrenosine, after washing during two days, had lost so much substance that only 0·859 grm. of dry compound were obtained.

0·4592 grm. gave 0·0364 grm. Cu O, equal to 6·32 °/₀ Cu.

These percentages of Cu and Pb do not admit of any theoretical explanation at present.

Indefinite Cerebrine Preparations, showing Peculiar Bearings of this Substance by itself, in Mixtures, or with Reagents.

Solubility in cold ether.

(1.) *Cerebrine (Ox; third portion of No. 12, before Stearoconote).*—This was dissolved in hot benzole, and precipitated by alcohol of 85 °/₀, washed therewith and dried over H_2SO_4. It was placed in ether, and shaken therewith repeatedly at the ordinary temperature; it became somewhat flaky in the ether. The ether extract, on distillation, left a few milligrammes of matter, which was soluble in hot alcohol, but deposited from it, on cooling, (cerebrine, myeline, or kerasine?). The cerebrine thus extracted with cold ether was now boiled in a great excess of ether, and filtered hot. From the filtrate a few unweighable particles separated on cooling. The filtrate was now distilled until it left a very small residue; this deposited on cooling a minute quantity of white

Solubility in boiling ether.

particles, soluble in hot alcohol, apparently cerebrine. Indeed, the extracted matter was so small in quantity that the extraction with ether was not continued. The cerebrine was analysed.

Analyses :— Analyses.

Dried at 60° to 70°.

(1.) 0·4423 grm. gave 1·0710 grm. CO_2 = 66·04 °/₀ C, and 0·4349 grm. H_2O equal to 10·92 °/₀ H. C. H.

(2.) 0·3736 grm. gave 5·6 c.c. N normal, equal to (after correction for a trace of nitric oxyde) 1·84 °/₀ N. N

(3.) 1·8706 grm. fused with nitre, &c., gave 0·0184 grm. $Mg_2P_2O_7$, equal to 0·27 °/₀ P. P.

The presence of P having been previously ascertained by qualitative testing only, its amount was expressly estimated on a large quantity of material.

Summary :—

	°/₀ found.
C	66·04
H	10·92
N	1·84
P	0·27
O	20·93
	100·00

If we neglect the P, the other figures lead to an empirical formula $C_{42}H_{83}NO_{10}$, which is not greatly altered if we deduct with the phosphorus a quantity of the other elements corresponding to myeline.

This experiment is stated only because its results are so consonant to the experience of former observers; the substance repeats the peculiarities of Couerbe's cerebrote, Frémy's cerebric acid, Gobley's and Thompson's cerebrine, Bibra's cerebric acid, and yet is unquestionably impure cerebrine, that is to say, a peculiar cerebrine with a large number of carbon atoms, to which a small quantity of myeline obstinately adheres, so that it cannot be removed by cold or boiling ether applied in any quantity. *By further experiment it was found that the myeline can be removed from the cerebrines only by dissolving them in hot absolute alcohol, allowing the cerebrine to deposit on cooling, and thereby keeping the myeline in solution. By repeating this process sufficiently often, cerebrines free from phosphorus are ultimately obtained.* Mere washing or boiling with ether does not remove the whole of the myeline, because this body is very little soluble in ether, and because it is probably mechanically enclosed by the cerebrine.

The bulk of the foregoing preparation was unhappily lost by an explosion and fire which occurred during the progress of its purification.

c. Sub-Group of Kerasines.

CONTENTS.

Kerasine.—$C_{48} H_{91} N O_9$.

This body belongs to the group of substances resembling cerebrine and phrenosine in general characters, but differing from it by well defined peculiarities, particularly by its late deposition from alcoholic solution, the form of its crystallisation, and its ultimate composition.

Mode of Isolation.—The ox white matter, which had been extracted with ether, and dried, was pulverised and dissolved in hot absolute alcohol, the solution was decanted from the fused mass of stearoconote and kephaline which formed, and allowed to deposit the dissolved matter by cooling. The deposit formed after the first hour was isolated, as was also another which formed after the second hour, a third gelatinous looking precipitate formed over night, and from this the absolute alcohol solution was filtered. On standing for a few days in stoppered bottles this solution deposited a gelatinous membranous mass, mainly consisting of *kerasine*. This was removed by the filter, and the filtrate which contained much *myeline* in solution was treated with $Cd\,Cl_2$. The white bulky precipitate of myeline $Cd\,Cl_2$ was filtered off, washed, exhausted with ether, and further treated as has been described elsewhere. It may be mentioned here that the principal bulk of myeline is obtained in this manner and at this stage. The alcohol filtered from the myeline $Cd\,Cl_2$ precipitate after concentration deposited a mixture of $Cd\,Cl_2$ salt, cholesterine, cerebrine, and kerasine, the latter two being present in very small proportions.

Mode of Purification.—Kerasine obtained as above is a soft white gelatinous mass, consisting of larger and smaller balls, which under the microscope are seen uniformly to consist of wavy masses of needles so thin that it may be said they possess only one diameter, namely, length. The gelatinous state is apparently entirely due to this peculiarity of the fine needles enclosing a large amount of alcohol. No amorphous matter whatever is seen mixed with it, but here and there a few rosettes of cerebrine, strikingly differentiated from the kerasine.

Purification by recrystallisation.

The whole of the kerasine was dissolved three times in boiling absolute alcohol, and after cooling to crystallisation washed and pressed free from mother liquor. This after the third operation was free from myeline, as shown by the absence of reaction with $Pt\,Cl_4$, $Cd\,Cl_2$, and Pb acetate, which give precipitates in even dilute solutions of myeline. The solution of kerasine was also free from myeline, $Cd\,Cl_2$ giving no precipitate with it.

Fractional crystallisation.

The kerasine was now dissolved in a fourth quantity of pure absolute alcohol, and allowed to crystallise. It was found by microscopic examination that after three hours much kerasine in wavy crystallised masses, but no cerebrine in rosettes, had been deposited. The crystals were consequently isolated, pressed, again recrystallised, collected on a filter, and dried in vacuo. This preparation only (1267) was analysed with the result stated below.

After this preparation had been removed, at the end of the third hour, from the mother liquor, the latter, on standing, deposited a mixture of much kerasine in wavy needles, with some rosettes of cerebrine. This mixture could by recrystallisation not be completely separated. A third ultimate precipitate seemed to consist mainly of cerebrine, with much kerasine, which could also not be purified by mere recrystallisation. These preparations were therefore put aside for future treatment (1267; 1268; 1269).

Properties of Kerasine.—Easily soluble in hot absolute alcohol, without leaving a trace of stearoconote. With $H_2 S O_4$ and sugar gives a purple test, which is mainly due to the production of purple particles, and not or only little to the production of a purple solution. Shrinks on drying by loss of enclosed alcohol to a very small bulk, and then becomes waxy, semitransparent, hard and horny. When quite dry is easily powdered, yielding a perfectly white powder. Easily dried at 100° C without any change.

Analyses.—(1.) 0·3670 grm. gave 0·9210 grm. $C O_2 = 68·446$ °/$_0$ C and 0·3764 $H_2 O = 11·395$ °/$_0$ H.

(2.) 0·5470 grm. gave 8·5 cc. gas at 18° C and 770 mm. B. K H O column = 16 m.m. Hg equal to 7·6 cc. N normal = 1·738 °/$_0$ N.

Summary :—

	°/$_0$ found.	÷ by At. Wts.	÷ by N=1.
C	68·446	5·704	46·0
H	11·395	11·395	92·0
N	1·738	0·124	1·0
O	18·421	1·151	9·2
	100·000		

leading to formula $C_{46} H_{91} N O_9$. This formula is given with all reserve. The analyses are not controlled by repetition, the molecule is with difficulty only determined by one atom of nitrogen united with so much carbon as to represent 46 atoms. But the purity and uniformity of the substance must be insisted upon. There is probably a large quantity of it contained in the cerebrine matters, which are soluble in boiling alcohol, and contain no phosphorus. The third deposit indeed is always greatly gelatinous and iridesces blue like kerasine. But to effect a complete separation of these substances is a matter of great difficulty, and we must therefore direct our attention at first upon obtaining pure substance at all, by manipulating large quantities of products, then the study of the pure bodies will undoubtedly lead to effectual methods of complete separation.

Experiment with reference to Otto's Cerebrine.—The question was whether by addition of baryta-water to an alcoholic solution of mixed cerebrine bodies the cerebrine, phrenosine, and kerasine could be precipitated, and the cerebrine free from nitrogen, described by Otto, could be obtained. Some crude cerebrine mixture, fully extracted with ether, was used for the experiment. The mixture was obtained from both (ox) white and buttery matter, by ether, which deposited the cerebrine, &c., on cooling in the shape of a disc. All myeline was now extracted by dissolving the matter thrice in hot absolute alcohol and filtering the deposit. The deposit was again dissolved in hot absolute alcohol and tested as follows.

Experiment showing that Water added to this Solution produces no Precipitate while hot.—A portion of the solution was mixed gradually with hot water until it became permanently turbid, which required more than one-fourth the bulk of the alcohol; no precipitate ensued. On cooling the solution set into a gelatinous mass of hydrated cerebrine, &c. This proved that the water to be used in the baryta water in the following experiment could not be instrumental in producing the precipitate.

Experiment with Baryta-Water.—The bulk of the hot solution was now treated with cold baryta water, added drop by drop as long as a precipitate formed. The precipitate immediately on formation was white and granular, but after subsidence caked together and became a soft viscous flowing mass like stearoconote, which adhered to the glass. The liquid was decanted and filtered hot.

The Precipitate was a plaster-like mass, which set on cooling into a hard solid mass, and after drying was easily powdered. It was a baryta compound, or mixture of baryta compounds, and on analysis was found to contain much Ba.

The Filtrate deposited on cooling a trifling amount of white flaky matter, which was isolated by filtration, washed with alcohol, dried, and analysed for nitrogen by combustion with copper oxyde with all precaution. It contained two per cent. of N. One analysis absorbed all the material, which amounted only to a few per cents. of the matter which had been precipitated by baryta water.

What is proved by this experiment is that after complete precipitation by baryta-water the solution does not deposit a cerebrine body free from nitrogen. The experiment is not entirely paralled to that of Otto, who used, as he says, excess of acetate of lead with his brain-pulp, which was not used in my case. But it is not stated by Otto how this excess of lead-salt was admeasured or ascertained, and it is not easy to see how, if it had actually been used, any cerebrine whatever could have been obtained by boiling the insoluble product of the lead-treatment in alcohol. Further, Otto does not state the method by which he proved the absence of nitrogen from his product. I am therefore inclined to think that he overlooked the nitrogen, perhaps in testing his substance only qualitatively by the potassium test.

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§ Summary.

The foregoing research is a contribution towards a system of *chemical statics* of the brain, and occupies itself with brain matter as a whole, without separating white from grey matter; it isolates and scrutinises the several chemical constituents of nerve-matter, and endeavours, by the study and consideration of the peculiarities of each, and their combination, to obtain sufficient insight into normal and abnormal chemical functions to enable us in time to guide or to correct them.

It is thus found that this apparently so simple nerve-marrow is a compound and mixture of a large number of heterogeneous principles arranged in such a manner as to vanish completely from appearance as chemical individuals; the compounds so interpenetrate each other that the resulting material is apparently homogeneous, during life completely so, when seen with high powers of the microscope, and although in death the homogeneity partly vanishes, yet even the appearance of the cylinder axis cannot be utilised chemically at present, and the isolation and recognition of any ingredients is entirely dependent upon most circumstantial chemical proceedings.

During these proceedings the first striking fact which meets the inquirer is that nerve-matter contains abundance of water. This, in conjunction with the peculiar manner in which the water is contained, engenders a mobility of ultimate particles within certain limits of movement. It also gives penetrability by liquid diffusion, while excluding porosity and its capillary effects; by which means a ready nutrition by diffusion in one direction, and ready cleansing from the effete crystallisable products of life in another, are ensured. Consequently the brain as a whole is essentially made up of colloid matter, and may be compared to a colloid septum, on the one side of which is arterial blood and cerebrospinal fluid of the ventricles, on the other side however, is cerebrospinal fluid of the arachnoideal space and venous blood. It follows from this that the large amount of water present in the brain, is not there so to say mechanically only, like water in a sponge, and capable of being pressed out mechanically, but is chemically combined as colloid hydration water, or better, *water of colloidation.*

All soft organs of the body contain about three quarters of their weight of colloidation water, fixed within the organised limits of cells and fibres of all kinds. Cells and fibres are thus apparently not very different in respect of their mechanical condition from brain matter. Indeed the difference is less in the manner of the condition than in the agents by means of which the condition is brought about. It is in effect mainly by the number and nature of these agents that brain matter is distinguished from other colloid tissues. It contains a considerable amount of an albuminous base. Whether this is distributed in the form of sheaths to fibres of nerve marrow, or whether it is laid into hollow spaces between the fibres, and acts as a cement, whether it is mixed or combined chemically with the rest of the matters constituting nerve marrow, cannot be here discussed. It may be present in all forms, but does not seem to be present in a liquid unattached form, as in serum. It appears that the bearing of soluble albumen when placed in presence of some of the peculiar brain matters changes from that which it ordinarily observes, no doubt by an influence of these brain matters amounting almost to combination. The bearing of albumen in the brain being thus seen to be governed by the matters peculiar to the brain, the present research has in the first instance not been directed upon the condition and nature of the albumen in the brain, but upon the peculiar matters which seem not only to govern the albumen, but by their manifold chemical affinities assist prominently in producing its singular mechanical arrangements, chemical function, and sensory, and volitional action and reaction.

It is not asserted that these matters, or any of them, occur exclusively in brain matter, but being present in the nerves, they consequently can be extracted from all sensitive or contractile tissues. They, or some of them, also occur in aggregations of loose cells, such as the blood-corpuscles and pus-corpuscles; others are present in serum, and others again in secretions, such as bile; but the quantities in which these bodies are met with in parts and matters other than those of the nervous system is very far less than that in which they occur in the nervous system.

The great quantity of these matters occurring in the brain forms three groups; the members of one contain five elements, amongst which is phosphorus; hence they may be termed PHOSPHORISED BODIES. The members of the second group contain four elements, amongst them nitrogen, but no phosphorus, and therefore are termed NITROGENISED BODIES. The members of the third group contain only three elements, carbon, hydrogen, and oxygen, present also in the other two groups,

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but neither phosphorus nor nitrogen, and may be termed OXYGENISED BODIES.

The group of the PHOSPHORISED bodies contains the phosphorus in the form of phosphoric acid, combined proximately with glycerine, so that by chemolysis they all yield glycero-phosphoric acid, but they differ in the manner in which they contain the nitrogen, and the acid radicles which constitute the great bulk of their substance, and according to these differences must be divided into sub-groups. We thus obtain the sub-groups of the *kephalines*, *myelines*, and *lecithines*.

Of these the *kephaline* sub-group, itself hitherto unknown, includes members which contain the nitrogen in either one or two forms, one being either choline or neurine, another hitherto unknown; and they contain the fatty acid radicles also in forms with which chemistry is at present unacquainted, and the members of this sub-group further vary in the amount of oxygen which they contain in a manner so as to be sharply characterised thereby. This variability of the constituent oxygen may be transitional, but must not be confounded with that remarkable reaction of the bodies of this group which I describe as their oxydisability.

The *myeline* sub-group, also new, contains the nitrogen in two forms, of which one is choline, the other amide in a fatty acid radicle. The fatty acid radicles vary, and are mostly new forms, some known forms. The members of this group consequently vary in carbon, hydrogen, and oxygen; little in nitrogen, never in phosphorus. They are not oxydisable after the manner of kephaline, though there is an oxy-myeline after the manner of oxy-kephaline. They are the least soluble of the entire group, the least decomposable, and stand the highest temperatures, being unchanged by fusion at a heat above the boiling point of water.

The *lecithine* sub-group, well known from the chemistry of eggs, is only with difficulty evolved from the brain, on account not only of the many stages of the processes necessary for their isolation, but also on account of a prominent feature of its members, namely, their readiness to decompose when in the anhydrous state. This tendency to apparently spontaneous lysis into proximate nuclei prevents the inquirer fixing properties and varieties with the same precision as in the previous groups; but it furnishes a valuable key to the explanation of many changes in the sick body, which may arise, or have been proved to arise, from their decomposition.

The chemical characteristics of these sub-groups may be summarised thus: the kephalines possess the tendency to be oxydised, oxydisability; the myelines are not easily changed by any agent or influence, and possess therefore stability; the lecithines easily fall to pieces, they are afflicted with lability.

In language more technically chemical: the *kephalines* have on the outside of their molecules free affinities for oxygen; this gas they bind in several ways; when the oxygen, combined with a molecule has attained a certain quantity, the avidity (intensity of affinity) of the molecule increases to this extent, that it monopolises all available oxygen to itself until the limits of its oxydisability (at present unknown) are attained; until its free affinities are satisfied. Until then the rest of the molecules, if the supply of oxygen be insufficient to oxydise all to the same point, are not oxydised. The kephalines, however, are not in a state of atomic tension, and therefore do not fall to pieces so easily as the lecithines, but require for lysis the influence continued for some time, of powerful extraneous affinities in the presence of water and heat.

The *myelines* have no apparent free affinities for oxygen; they are not affected by heat to and above boiling water except to the extent of fusion; their atoms are not in a state of chemical tension, but require

for vibration into permanent decomposing distances the influence of strong external affinities, water and heat.

The *lecithines*, however, are in a state of great atomic tension, and therefore slight external affinities or dissociating impulses suffice to effect their decomposition. Such a slight impulse is the attraction of absolute alcohol for their fatty acid radicles in the absence of external water. The water given out by the alcohol in becoming ethylic ether serves to enable the radicle of glycerophosphoryle to become glycerophosphoric acid, and to remain in combination with the choline evolved.

The presence of water diminishes the number or avidity of affinities in in all these sub-groups; it combines itself with these bodies in a peculiar manner, by which they show their character as colloids, and it afterwards dissolves them in a peculiar and imperfect manner. When this hydric colloidation is at a maximum, the dissociating faculties of the members of these sub-groups seem to be at a minimum. The watery solutions do not decompose in stoppered bottles for many months; only after six months some specimens so kept showed signs of decomposition or putressence. It seems therefore that water satisfies some of these affinities, and what is most remarkable, its influence increases and diminishes with the mass which is present and capable of acting, so that it displaces, when in quantity, other combinants, but when these other combinants prevail, water is itself displaced, and the colloid state instantly disappears. In the dilute watery solutions of the phosphorised bodies therefore almost every reagent soluble in water, when added in a certain excess, produces a precipitate, which contains the reagent in combination. But when water, or any watery solvent capable of dissolving the combined reagent, is brought in contact with the compound, the compound immediately dissociates; the reagent passes into the water, *pari passu* as the phosphorised body passes into the hydrated colloid state, and if the influence of the water is continued by renewal, the process terminates by a complete separation; the phosphorised body is again free and pure, and swells and dissolves as at first.

The reagents with which the phosphorised bodies are thus able to combine, and from which they are dissociated by water, are acids, alkalies, and salts. The phosphorised bodies therefore possess alkaline affinities (for acids), acid affinities (for alkalies), alkaloid affinities (for salts); all these affinities are overcome by water in quantity, but the affinities for water are overcome by some metallic oxydes, such as of lead, copper, manganese, iron, and even to a slight extent by lime and potash; these latter compounds are dissociated only by strong mineral acids, and the compounds can then be dialysed out. All other combinants separated by water alone can be completely removed from the phosphorised substances by dialysis on a diaphragm of parchment paper.

We have therefore here a diversity of affinities such as is not possessed by any other class of chemical compounds in nature at present known; and the exercise of these affinities being greatly influenced by the mass of reagent, and the mass of water which may be present, the interchange of affinities may produce a perfectly incalculable number of states of the phosphorised and consequently of brain-matter. This power of answering to any qualitative and quantitative chemical influence by reciprocal quality or quantity we may term the state of *labile equilibrium;* it foreshadows on the chemical side the remarkable properties which nerve-matter exhibits in regard of its vital functions.

From this it also follows that nerve-matter (if only as characterised by the phosphorised bodies) must yield obedience to every, even the slightest external chemical influence, which may reach it by way of the blood. It must take up metals, acids, salts, alkalies, and alkaloids presented by the blood; it can retain only oxydes when the serum is again

free from the combinants; a watery serum will wash the brain, a more watery one will make it swell and displace mechanically within physiological limits what it can; a still more watery one will make the brain dropsical and produce all the conditions of mechanical pressure on the brain. All these processes are the necessary consequences of the affinities of the phosphorised substances, and these being known the phenomena could be predicted, if they were not sufficiently known as phenomena, though hitherto destitute of an explanation. Thus the so-called brain-fungus, the continued protrusion of brain-matter through apertures of the skull produced by mechanical injuries, may in certain cases find a physical explanation in simple excessive hydration of the phosphorised (and nitrogenised) principles, producing general intra-cranial pressure.

These few examples show that the acquisition of chemical statics leads almost necessarily and very easily to chemical dynamics of the brain; and these will in their turn furnish data for physiological and pathological conclusions. But these deducive arguments must be most sparingly and cautiously used, until the statics are in a state of perfection and completeness. To argue too far from incomplete data would, seeing the history of biological chemistry during the last thirty years, be a deplorable error.

The NITROGENISED substances of the brain imitate in many respects, but in a lesser degree, the properties of the phosphorised. Thus they have the affinity for water to the extent of swelling to gelatinous masses, but they do not go to the state of apparent solution, and do not pass paper filters under any pressure. They are insoluble in ether, cold benzole, cold alcohol; dissolve in hot benzole or alcohol, and are deposited on cooling almost entirely. Therefore as compared to the phosphorised bodies, their chemical character is slight solubility; from their hydrated colloid state they are also reduced to a more compact and combined one by many acids, alkalies, and salts, and they retain many oxydes in combination. Water has the same dissociating influence upon these as upon the compounds of the phosphorised principles. There are, however, slight differences. The nitrogenised bodies are all firm compounds, and do not easily oxydise or decompose. Their atoms show very little tension; but they possess substitution poles, where hydrogen is replaceable by metalloids, or compound radicals; and these compounds seem more stable, and to admit of isolation to some extent, while the compounds with salts, oxydes, or acids, are so unstable as not to admit at present of quantitative definition.

The members of both the phosphorised and nitrogenised groups are all, as stated, strictly colloid, and do not pass through the septum of a dialyser. In accordance with this they show only little tendency to crystallise under any circumstances; several have not been observed crystallised or crystalline at all, *e.g.*, the kephalines and lecithines; the cerebrines and phrenosines may be just termed crystalline when slowly deposited from alcohol; the myeline and kerasine are undoubtedly crystallised when deposited slowly from alcohol, but the forms are microscopic.

The presence of a trace of water effaces all crystalline forms, and leaves the shapeless colloid. Thus the definition by Graham of colloids, which did not exclude their power to crystallise under limited conditions, is fully borne out by these cerebral principles.

The third group, isolated, but not specially discussed or studied in the research, that of OXYGENISED principles, consists mainly of alcohols with very slight combining power. The most prominent one of these, both as regards quantity and appearance is *cholesterine*. Discovered originally in human gallstones, and erroneously believed to be a fat, this principle received the inappropriate name which hides its signi-

ficance and character. Insoluble by itself in water, it is probably dissolved in brain matter by means of the phosphorised substances. Its bearing is therefore governed and its role determined to a great extent by these matters. But its intrinsic chemical dynamis is probably also independent, to some extent, as its atomic weight is very high. As an alcohol it is monodynamic, and if it did combine with acid radicles naturally would therefore give rise to one class of ethers only. If such compounds exist in the brain, they must be in a state of high atomic tension, and fall to pieces by the mere fact of the application of solvents. These and other questions concerning this class of bodies, belong properly to the chapter of chemical dynamics upon which this research has had no opportunity of entering. The other oxygenised principles have not even been treated statically, and are therefore not disturbed from their historic slumbers.

There is met with at almost all steps of the separation of the ingredients of white matter, a substance distinguished by fusibility and insolubility in boiling alcohol, which by Couerbe was named *stearoconote*. Although not treated of in the present research a few explanatory notes regarding it may properly be given in this place. When white matter is placed into a quantity of hot alcohol, most cholesterine and lecithine and some cerebrine dissolve, but the other phosphorised and nitrogenised matters immediately fuse into a plaster-like mass, which is then practically insoluble in boiling alcohol. There is therefore here an attraction produced by the fused state which removes the solubility of some of the ingredients of the mass in alcohol. When the principal matters soluble in ether, *i.e.*, the kephalines, are now extracted, the fusibility is diminished, and some of the cerebrines dissolve more freely in hot alcohol. Stearoconote, however, still forms, and is now a reaction mainly of myeline and the cerebrines. When all myeline is separated from the cerebrine group of bodies, their power of forming stearoconote is depressed to a minimum, but not entirely removed. Myeline by itself also retains this tendency of forming a fused mass insoluble in boiling alcohol, which in the text has been termed a tendency to stearoconotise. The phenomenon seems to be compound, and not simple, and to consist in essence of a molecular change without attendant change in quantities of atoms of elements. For I have found that some stearoconote, free from phosphorus could by treatment with benzole and little hydrochloric acid be transformed into cerebrine, which on elementary analysis was found to have the same empirical composition as the stearoconote from which it was made. In this case no separation of a base from the cerebrine could be proved to have taken place. In other cases it was found that the stearoconote obtained its solubility in alcohol without the intervention of acids, by standing in benzole, in which it is easily soluble. Again, in other cases it was probable that the stearoconote was really a compound of some nitrogenised body with a mineral base, and bodies resembling the stearoconotes in some respects, but not in all, were produced by adding bases to solutions of the cerebrine series. On the whole, then, "stearoconote" does not seem to be a chemical individual differing from the other bodies described, but a function of several bodies, which pass into that state by a molecular change, which change can be made to retrograde into the originally soluble condition.

The function is a result of chemical and physical influences acting simultaneously (alcohol and heat) and is apparently not obtained by either influence separately. Stearoconote seems, therefore, a product, and not an educt; but it is indirectly important, as showing that there is some peculiar attraction or mutual influence between the bodies of the two great groups. In white matter where those brain-principles are all

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mixed together nearly in their original proportions (only lecithine being much diminished in quantity) the above influence has its highest intensity. The function diminishes with increased separation, *i.e.*, increased purity of educts. It is entirely lost in some of the educts, when they are in the pure state; thus pure kerasine could by no means be made to yield any stearoconote. But it remains with others, particularly myeline and cerebrine in the pure state, and is evoked when they are subjected to the influence of heat in the presence of a quantity of alcohol insufficient to dissolve the whole of the material before it has had time to fuse. Once fused, it seems to resist solution, even after repeated powdering to increase the surface for the action of alcohol, to the extent of being rather destroyed than dissolved.

In the phenomenon just described we observe as the main result diminished or suspended solubility, that is to say, suspension of the lowest form of chemical attraction. In a phenomenon now to be pointed out, we perceive however, on the contrary, the production or elicitation of a solvent power of a kind hitherto quite unknown in animal chemistry. The phosphorised bodies, when combined with metals or metallic salts, in the presence of ethylic ether, and whether dissolved in it or not, cannot be separated from these metals by hydrothion. The dissolved compounds assume the colour of the respective sulphide, and remain dissolved; the compounds insoluble in ether immediately pass into solution when the hydrothion gas is passed through the mixture. Thus, cadmic chloride compounds dissolve with a canary yellow colour; platinic chloride compounds with a dark brown colour; lead compounds with a red or blackish-red colour. The compounds can be partially or entirely precipitated by water, or alcohol, or ammonia, &c. They contain, in addition to the phosphorised body, in the cases of chlorides, chlorine and sulphur, besides metallic sulphide; in the case of metals like lead, metallic sulphide and sulphur. Their complication places them at present beyond the reach of stoechiometric treatment.

When once thus combined with sulphur (or hydrothion) and metallic sulphide, or with these and chlorine in addition, and precipitated and isolated, the phosphorised bodies can by no means ordinarily at hand be again obtained in the free state. They then behave, as they do in solution, somewhat like combinations of mercaptans with metallic sulphides. The compounds with metals of the phosphorised bodies can be decomposed by hydrothion only while suspended in water; the product, a mixture of metallic sulphide with the respective body, must then be washed with water until pure, and the respective body extracted by a suitable solvent.

The obstacles which these extraordinary properties of the chemical principles of the brain throw in the way of chemical procedure are perfectly indescribable. To use a simile from military life, the biologist who attacks his problem in front is beaten off at all points; he can only conquer it by flanking on long and circuitous routes, and by the use of instruments of warfare which are either new or superior to those hitherto in use.

These difficulties increase with every step which leads nearer to the consummation of the purpose, and are greatest at the point where the isolated chemical individuals are to be freed from the last traces of admixed impurity. The very peculiarities of the principles described are mostly negations of the properties ordinarily relied upon as criteria of chemical purity. On this matter I have repeatedly dilated in the text, and given expression to apprehensions as well as to considerations calculated to remove them. As the difficulties arose they were followed out experimentally, one by one, step by step, to the exhaustion of the known means at hand, or of the new means that could be devised in the

time. But it must be left to the future to increase, if possible, both the means of producing, and also the criteria for insuring, that absolute purity of ultimate educts which is the condition of certainty in chemical science.

It is therefore not asserted that in the foregoing research the absolute limits of the subject have anywhere been reached. But it is confidently believed that its entirety has been explored in such a manner that fundamental truths cannot have escaped observation, and that what remains to be done is essentially of the character of detail, which, however vast by multiplicity it may become, will not alter the broad outlines which this investigation has led me to state.

While then there may be some degree of uncertainty as to the absolute purity of some of the principles evolved, there can be none as to their striking individuality; and, as regards this, the positive evidence of their peculiar and distinctive qualities is so strong that the fact of their not uniformly answering to certain other criteria is, in my opinion, quite insignificant.

Thus the solubilities of kephaline separate it widely from all other brain matters; its reddish colour and green fluorescence when manipulated in air cause it to be recognised in very dilute solutions. By analysis it exhibits an amount of oxygen exceeding from one third to one half that of other phosphorised matters. By chemolysis it yields not any known fatty acids, but fatty acids hitherto unknown, and a portion of its nitrogen also in forms hitherto unknown.

Again, the solubilities of myeline and of its compounds admit of being used for its easy and complete separation from kephaline on the one, and lecithine on the other, hand. Its positive properties all exclude kephaline and lecithine easily, less easily the bodies of the cerebrine group; but these are entirely differentiated by benzole, to which they oppose a perfect insolubility.

The separation of lecithine from kephaline must on the face of the processes be complete; the separation of all kephaline from lecithine is, however, at present not to be absolutely ensured, and the circuitous proceedings necessary to approach the purpose seem to be fatal to the stability of the principle to be purified.

The distinction of individuals is more difficult in the cerebrine group, the members of which are more similar to each other in the properties as yet known. Of the individuality of kerasine there can, I think, be no doubt; at least if strictly uniform crystallisability be of any value as a criterion. More doubt may be allowed in the matter of phrenosine, where these doubts have led me to a great number of experiments to establish the purity and fix the size of the molecule. As regards the rest of the group the information given is little more than a preliminary pioneering account, valid as far as it goes, but not in any particular of a final nature.

Such information can probably only be secured hereafter by the manipulation of quantities of material on a scale such as no enterprise in biological chemistry has hitherto had the opportunity of adopting. In particular it is just the necessity for the ultimate perfect purity of the principles to be established which creates the necessity for the manipulation of large quantities.

It gives me pleasure to have this opportunity of acknowledging and recording the uniformly assiduous, able, and skilful help which I have received during almost the whole of this research from my assistant Mr. C. T. Kingzett.

App. No. 5.

On the Chemical Constitution of the Brain, by Dr. Thudichum.

III.—ALPHABETICAL LIST OF CHEMICAL EDUCTS (IMMEDIATE PRINCIPLES) AND PRODUCTS (BY CLEAVAGE OR SYNTHESIS), STATED TO HAVE BEEN FOUND IN OR PRODUCED FROM THE BRAIN OF MAN AND ANIMALS; WITH NOTES CONCERNING PROBABLE IDENTITIES AND SYNONYMS.

Note.—The substances marked with an asterisk thus* are believed to be now described for the first time as ingredients in brain matter. The substances marked with dagger † are recognised as mixtures, or lack the characteristics of chemically defined simple bodies, and it is therefore proposed to discontinue the names. The educts include not only normal constituents, but also accidental ingredients.

SYNOPSIS OF NAMES.

1. Acetic acid.
2. Acid, new, containing P and S.
3. Acids, Liebig's, two new.
4. Albumen.
5. Albuminous matters.
6. Alcohol.
7. Ammonia.
8. Amyloidine.
9. *Apomyeline.
10. Arsenic.
11. *Base, new, from kephaline.
12. *Buttery matter.
13. Caseine.
14. †Céphalote.
15. †Cerebric acid.
16. Cerebrine.
17. *Cerebrinic acid.
18. †Cérébrote.
19. Chlorides.
20. Cholesterine.
21. Choline.
22. Copper.
23. Elaine.
24. Elastine.
25. †Eléénc éphole.
26. Extractives.
27. Formic acid.
28. *Glyceramine.
29. Glycerophosphoric acid.
30. *Hydrothion.
31. Hypoxanthine.
32. Inosite.
33. Iron.
34. *Kephaline.
35. *Kephaloidine.
36. *Kerasine.
37. *Kephalic acid.
38. Kreatine.
39. Lactic Acid.
40. Lead.
41. Lecithine.
42. Leucine.
43. Leucine homologue.
44. Manganese.
45. Margaric acid.
46. Margarine.
47. Mercury.
48. *Myeline.
49. †Myeloidine.
50. †Myeloidinic acid.
51. †Myelomargarine.
52. Neurine.
53. †Neurolic acid.
54. *Oily, last, matter.
55. *Oleate of ethyle.
56. Oleic Acid.
57. Oleine.
58. †Oleophosphoric acid.
59. Osmazome.
60. *Oxykephaline.
61. Palmitic acid.
62. Palmitine.
63. *Paramyeline.
64. *Peroxykephaline.
65. Phosphates.
66. Phosphorus.
67. *Phrenosine.
68. †Protagon.
69. *Pyrokephole.
70. Silica.
71. Stearic acid.
72. Stearine.
73. Stearoconote.
74. Sugar.
75. Sulphates and sulphur.
76. Syntonine.
77. Trimethylamine.
78. Urea.
79. Uric acid.
80. Water.
81. White matter.
82. Xanthine.

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1. *Acetic Acid* (Müller) obtained by distilling extracts to which lead acetate had previously been added. Therefore probably introduced by reagents, and not proved to be naturally present in brain.

2. *Acid, new, containing P and S,* found by me in human brains, which had been preserved in spirit. The same brains also yielded hydrothion and glycerophosphoric acid, from which it is probable that the sulphur became attached to the phosphorised body as a result of the decomposition of albumen. The observation is important as bearing upon the analytical results of Couerbe, who found sulphur in all his phosphorised brain extracts.

3. *Acids, Liebig's two new,* obtained as baryta-salts, of which one was soluble in alcohol. Not yet identified.

4. *Albumen.*—It is probable that the brain contains soluble albumen, but this has not yet been proved.

5. *Albuminous Matters.*—These remain in the insoluble state after all other matters are extracted from the brain by alcohol. They have been variously sought to be identified with caseine, elastine, syntonine, and others, but proofs are wanting. In particular Lehmann's surmise of the presence of caseine in the soluble form, based upon the observation that watery brain-extracts on heating or evaporation form skins on their surface similar to milk, is now of no value, since I have shown that most phosphorised bodies in the pure state, when heated in watery solution, form these membranes.

6. *Alcohol.*—Obtained from the brain by distillation after death from poisoning with spirit, or from chronic alcoholism, commonly termed delirium tremens.

7. *Ammonia.*—Present in the brain of man and animals; obtained from ultimate watery extracts, and found in combination with phosphorised bodies in very small quantities only.

8. *Amyloidine* (Virchow).—A matter found microscopically only, and not yet chemically isolated; a product of certain diseases, particularly locomotor ataxy, in which it occurs in quantity in the spinal marrow. When coloured blue by iodine in the presence and under the influence of sulphuric acid it closely resembles wheat starch in appearance.

9. **Apomyeline.*—Probably a product and not an educt, obtained by boiling the myeline hydrochloride platinic chloride in absolute alcohol. Possibly a dissociation ensues in the boiling solution, in consequence of which a new platinum compound is formed, which contains and yields this body.

10. *Arsenic.*—Found after acute and chronic poisoning.

11. **Base, a green-coloured.*—Obtained by chemolysis of some of the phosphorised compounds; its platinic chloride salt is soluble in absolute alcohol, and precipitated from this by ether.

12. **Buttery Matter.*—The mixture of kephaloidine, paramyeline, cholesterine, &c. obtained after the first concentration of the alcohol extracts of brains which have deposited white matter. A convenient term for a first crude product.

13. *Caseine* (Lehmann).—Inferred from the formation of membranes on evaporating watery brain extracts. As most of the phosphorised bodies show the same peculiarity, there remains no ground for the surmise, except the finding of potassium albumen in the NaCl solution with which brain has been treated. (See my Manual, p. 86, § 6.)

14. †*Céphalote* (Couerbe).—Mainly kephaline and kephaloidine, mixed with oxy- and peroxy-kephaline, their earthy, alkaline, and metallic salts, and much colouring matter. Stated to contain sulphur, probably erroneously, or if it did contain sulphur the latter was attached only, and not constituent.

15. †*Cerebric Acid* (Frémy).—A mixture of the cerebrine, phrenosine, kerasine class of bodies, with a certain small proportion of

myeline. Nearly the same as Couerbe's cérébrote and Gobley's cérébrine, Liebreich's protagon, and Bibra's cerebric acid. The phosphorised bodies met with in the brain contain from 5 to 20 times the amount of phosphorus which these authors found in their products. Moreover, none of these products could be free from cholesterine and bases.

16. *Cerebrine.*—Term first used by Kühn for a mixture of phosphorised matters and cholesterine, afterwards by Lassaigne for an alcohol extract of nerve substance, not any better defined. The same term afterwards used by Gobley for the mixture described in the previous § 15, containing P. Again applied by Müller to the substance free from P, $C_{17} H_{33} N O_3$. This latter terminology is applied exclusively in the present research.

17. **Cerebrinic Acid.*—Term applied in this research to some nitrogenous compounds of the cerebrine type, containing above 34 atoms of C, and evincing a greater combining power with lead, by means of which they are isolated.

18. †*Cérébrote* (Couerbe).—Mixture of bodies of the cerebrine type with some myeline, from which latter the mixture derives the small amount of phosphorus which it contains. See § 15 above, Cerebric acid.

19. *Clorides of Potassium and Sodium.*

20. *Cholesterine.*—The same as found in gallstones. This identity first announced by Gmelin, first proved by chemical analysis by Couerbe.

21. *Choline.*—Ammonium base, discovered by Strecker as a product of the chemolysis of lecithine in bile. Identical, or nearly so, with neurine.

22. *Copper.*—Normally present, according to my researches, as a base in small quantities in combination with the phosphorised bodies, and also in somewhat larger quantities in the albuminous part of the brain of both man and the ox.

23. *Elaine.*—The solidified form of oleine. Doubtful.

24. *Elastine*, the fibrous tissue which forms the ligamentum nuchæ and the elastic coats of arteries, is supposed by some to be a constituent of the structural connective base of the brain. Lacks definite proof.

25. †*Eléencéphole* (Couerbe). — Berzelius proposed the term *cerebrole*, which was never adopted. Mainly the "last oily matter" of the present research, but believed by Couerbe to be a simple substance. It contains no doubt portions of the greater number of phosphorised bodies, which can be extracted from it. Cholesterine cannot be entirely removed from it. Its oily character is probably derived from the presence of a considerable amount of oleate (and margarate) of ethyle, formed during the processes from decomposing lecithine and perhaps other matters. Stated by Frémy to be oleine, but this is improbable, on account of data to be stated under oleate of ethyle. Gobley and myself never found any oleine.

26. *Extractives.*—The water extract has an agreeable odour of broth, *osmazome* of the older authors. It contains *acids* resembling in bearing those which I have described elsewhere under the name of kreatylic acid (from flesh), and kryptophanic and paraphanic acid (from urine).

27. *Formic Acid* (von Bibra).—Found (in human brains only, Müller) amongst the products of distillation of brain extracts with acid.

28. **Glyceramine.*—Probable product of the chemolysis of kephaline. Possibly only isomeric with Berthelot's product of that name. To be considered as hypothetical.

29. *Glycerophosphoric Acid.*—Product of chemolysis of the phosphorised substances, and therefore a proximate constituent of all of them. First observed by Gobley in Pelouze's laboratory, where the acid had

shortly before been synthetically prepared by Pelouze. Found in diseased brain by Lehmann.

30. **Hydrothion.*—Probably only as a product of physiolysis of the albuminous part of brains kept in spirit; observed by myself.

31. *Hypoxanthine* (Müller).—Not definitely proved.

32. *Inosite* (Müller) in ox brain, not in the brain of man. Definitely proved and isolated in relatively large quantity.

33. *Iron.*—Always present in combination with some phosphorised bodies, and in the albuminous part.

34. **Kephaline.*—The principal and most remarkable phosphorised ingredient of the brain of man and the ox. Was contained in the céphalote of Couerbe, but missed or neglected by all subsequent inquirers. Occurs in part regularly combined with K, Na, Ca, Mg, Fe, Cu.

35. **Kephaloidine.*—A phosphorised body, very similar in constitution and properties to the former, but differing slightly by being less solid and cohesive.

36. **Kerasine.*—A nitrogenised body of the cerebrine type, free from phosphorus; crystallises in globules of microscopic needles.

37. **Kephalic Acid.*—Product of the chemolysis of kephaline.

38. *Kreatine* (Müller).—In human brains only.

39. *Lactic Acid.*—Von Bibra.

40. *Lead.*—In fatal cases of chronic lead-poisoning.

41. *Lecithine.*—Discovered in eggs by Gobley, who believed the phosphorised matters of brain substance to consist of lecithine only, although he could not isolate it, and then assumed cerebrine (supposed to be phosphorised) to be present besides lecithine. This erroneous conception has been maintained down to the present time by many authors, who admitted only lecithine, sometimes of two kinds—di-oleyl and di-stearyl lecithine, and entirely neglected the totally different bodies of the kephaline group. According to my research, lecithine is probably present in the brain, but is most difficult to isolate in a pure state; it decomposes almost entirely during the process of purification from kephaline, with which it is necessarily largely mixed. Occurs combined with K, Na, Ca, Mg, Fe, Cu.

42. *Leucine.*—Not definitely proved.

43. *Leucine-homologue, containing* C_5 (Müller).—Hypothetical; not definitely proved.

44. *Manganese.*—Accompanies iron in the phosphorised and albuminous ingredients, and is always present in notable quantities.

45. *Margaric Acid* (Gobley).—According to this author, a constant product of the chemolysis of the viscous matter, containing lecithine, from brain; obtained by Strecker from egg-lecithine. Formulæ and fusing point of acid uncertain, which leaves the question open whether different brain matters do not yield different margaric acids. This acid should therefore not be rashly confounded with a mixture of stearic and palmitic acid. I have not as yet obtained any solid fatty acid from brain-matter which had a fusing point above 52° C.

46. *Margarine.*—Not proved. *See* stearine and palmitine.

47. *Mercury.*—In cases of death from chronic poisoning by mercury.

48. **Myeline.*—This name was applied by microscopists to various extracts of animal tissues and fluids which they examined microscopically, and which showed a peculiar bearing with water (swelling). These extracts no doubt contained mixtures of all the phosphorised bodies, but no single substance was chemically identified. I therefore adopt the

name only for my definite chemical educt, and attribute little diagnostic value to the microscopic myeline forms, so called, which are produced by most or all bodies of the phosphorised groups, and in a certain degree also by the bodies of the cerebrine groups. Occurs combined with K, Na, Ca, Mg, Fe, and Cu.

49. †*Myeloidine* (Koehler). — A phosphorised body, found and analysed by this author as lead-salt; corresponds to one of the myelines of my research in which N : P = 1 : 1.

50. †*Myeloidinic Acid* (Koehler).—Mainly bodies of the kephaline group, with considerable impurities.

51. †*Myelomargarine* (Koehler). — Mixture of products obtained by the influence of sulphuric acid and alcohol and two hours' boiling upon the mixture of the cerebrine group of bodies. Said to be free from nitrogen, but this is not proved.

52. *Neurine* (O. Liebreich).—Product of the chemolysis of the supposed protagon, being actually the ammonium base yielded by the myeline and lecithine groups of bodies, and identical with, or nearly identical with, choline, obtained by the same processes from the lecithine of bile (Strecker).

53. †*Neurolic Acid* (Koehler).—A product of decomposition of phosphorised matters, dissolved probably in oleate of ethyle.

54. *Oily, Last, Matter*.—Convenient term for the semifluid mixture of substances, obtained by the last evaporation of brain-extracts; is, or contains, Couerbe's élééncéphole.

55. **Oleate and Margarate of Ethyle*.—Products of decomposition and combination, probably. Lecithine seems to decompose easily, and its acids, in the status nascens, in the presence of alcohol become ethers. They settle as an oily matter from alcoholic solution, from which all matters precipitable by lead acetate, cadmic chloride, and platinic chloride have been removed. This seems to be Couerbe's élééncéphole in its purest state, and Frémy's "oleine nearly pure." Its bearing on distillation, above 360° C., is quite different from that of either oleine or oleic acid.

56. *Oleic Acid*.—Product of chemolysis of phosphorised substances, notably of lecithine; obtained always together with margaric acid, the latter in largest quantity on the whole. First obtained by Gobley from brain-matters.

57. *Oleine* (Frémy). — The statement of this author will be criticised in the survey; his analyses do not support his assumption. Gobley and myself never found oleine, declared by Frémy to represent the élééncéphol of Couerbe; therefore, possibly, Frémy's oleine is mainly oleate of ethyle, a product of the reaction between decomposing lecithine and the alcohol used for extraction.

58. †*Oleophosphoric Acid* (Frémy). — From the insolubility of the acid in alcohol it might be supposed that the substance was mainly composed of bodies of the kephaline series. But these contain all nitrogen; Frémy's body is said to have been free from nitrogen. No inquirer after Frémy has ever found this oleophosphoric acid, and Frémy himself avows that he never had it pure. He never analysed it, and therefore may have overlooked the nitrogen. On the whole I coincide with Gobley's criticism of this acid, and, after many vain endeavours, abandon any further attempts at its interpretation.

59. †*Osmazome* (Vauquelin). — The last water-extract, containing all substances soluble in water, and having while hot, a most agreeable odour of broth, which is much finer than that of the purest meat extract.

60. **Oxykephaline.*—A substance of the kephaline group, containing an atom of oxygen more than kephaline, and being more decided in its combining tendencies. Kephaline being somewhat oxydisable under the influence of oxygen, this body might be a product; but this is not proved, and the substance must therefore stand as an educt.

61. *Palmitic Acid.*—Supposed ingredient of margaric acid. See however, the note on this latter acid.

62. *Palmitine.*—If Frémy's derivation of Gobley's oleic acid from oleophosphoric acid (should be oleinophosphoric acid, because supposed to contain oleine in combination with phosphoric acid), were correct, then, says Gobley, he would be compelled to derive his margaric (palmitic and stearic) acid from some margarine (palmitine and stearine), which must be supposed to be decomposed by his process. But solid neutral fats have never been found in brain, and therefore the presence of palmitine is highly improbable.

63. **Paramyeline.*—A phosphorised body, similar to myeline, and also to lecithine, but differing in particulars from both.

64. **Peroxykephaline.*—A phosphorised substance of the kephaline group, containing two atoms of oxygen more than kephaline, and one more than oxykephaline; the most precise body of the group as regards its combining power.

65. *Phosphates* of potassium, calcium, magnesium, and perhaps other metals.

66. *Phosphorus.*—Early brain researches contain evidence of many inquiries after the form in which phosphorus is present in the brain, particularly search after "phosphorus as such," or P in the metalloid form was made. But it is now almost certain that the phosphorised organic matters all contain P in the form of phosphoric acid combined with glycerine, and yield this nucleus by chemolysis as glycerophosphoric acid. It is, however, possible that *some* phosphorised matters contain P in two forms, of which the second, not yet fully known in particular, is not yet proved to appear as glycerophosphoric acid by chemolysis, but remains attached to one of the fatty acid radicals of the combination as kephalophosphoric acid.

67. **Phrenosine.*—A nitrogenised substance of the cerebrine type, containing only half as much nitrogen as cerebrine. Forms substitution products with Br and NO_2.

68. †*Protagon.* (O. Liebreich).—A mixture of much cerebrine, phrenosine, kerasine, &c. with myeline and some kephaline, also some holesterine. Was, therefore, mainly Couerbe's cérébrote, Frémy's rebric acid, but contained a little more myeline than these preparaons, which raised its phosphorus a little higher. The neurine which yielded by chemolysis came from the myeline; the supposed new fatty acid ("vibrating mass"), a mixture of several fatty acids also; the sugar-like body, which reduced copper solution, came from the bodies of the cerebrine group. Its hydrogen was found so high, that it cannot be disposed off by any easy hypothesis.

69. **Pyrokephole.*—Distillation product of (perhaps impure), oleate of ethyle; on analysis gives figures which show it to be empirically isomeric with oleic acid. Perhaps a mixture. According to Laurent, oleate of ethyle distils unchanged; according to others it decomposes completely. If decomposed, it is so in this case without much destruction, that is to say, it is rather permanently dissociated by the effect of heat (thermolysed), than burned at the expense of its oxygen.

70. *Silica.*—Found by some older authors; but uncertain whether derived from glass and porcelain vessels or glace of earthenware.

71. *Stearic Acid* (Diakonow).—Said to have been obtained by chemolysis of lecithine, which this author describes as containing two nuclei of stearyle. Not found and doubted by Strecker.

72. *Stearine.*—To this substance the remarks on palmitine and margarine apply.

73. *Stearoconote* (Couerbe).—A body obtained in small quantities with and from the cerebrine group of bodies; it is insoluble in boiling alcohol and soluble in cold benzole. Can be artificially produced from cerebrine bodies, which I then term "stearoconotised," and retransformed into cerebrine. Erroneously declared by Frémy to be albumen. Müller's resinous drops. Compounds of cerebrines with bases and salts also imitate the features of stearoconote.

74. *Sugar.*—Diabetic sugar in cases of death from diabetes mellitus.

75. *Sulphates and Sulphur.*—The former as inorganic salts, the latter in organic combination in albuminous matters; as physiolytic product, probably in slow decomposition of the brain, in the form of hydrothion, q. v. The finding by Couerbe of sulphur in his phosphorised bodies is no doubt an error caused either by impure reagents (nitric acid) or by decomposition. The normal phosphorised and nitrogenised brain-matters (albumen excepted) contain no sulphur.

76. *Syntonine.*—Supposed to be contained in the insoluble albuminous residue of brain. Not proved.

77. *Trimethylamine.*—Found by me in decomposing brains; perhaps derived from decomposing neurine or choline (of which Mauthner showed that it yielded trimethylamine when kept for some time in the presence of putrescent matter).

78. *Urea.*—Probably always present in small quantities; accumulates in diseases in the brain to such an extent that the cerebro-spinal fluid, in cholera for example, contains as much as two per cent. of urea, that is to say as much as ordinary urine. *See* Report, 1866, p. .

79. *Uric Acid.*—(Müller), in ox brain, not in that of man. But the identity is not well proved.

80. *Water.*—Nearly four-fifths of the weight of the brain consist of water.

81. *White Matter* (Vauquelin). The total deposit from first hot alcohol extract of brain deposited on cooling. A convenient designation of a bulky crude product containing the ingredients enumerated elsewhere, mainly the group of the cerebrines, kephalines, myelines, and cholesterine. This is sometimes erroneously identified with Couerbe's cerebrote and other substances already more simple.

82. *Xanthine.*—A substance like this body occurs in brain; but its nature is not certainly established.

IV. *Historical Account of previous Researches.*

LIST OF AUTHORS AND DATES OF THEIR PUBLICATIONS.

Hensing, 1715.	Frémy, 1841.
Spielmann, 1766.	Gobley, 1846–1856.
Mönch, Gurman, Burrhus.	Müller, 1857–1858.
Thouret, 1790.	Liebreich, 1864.
Fourcroy, 1793.	Koehler, 1867–1868.
Vauquelin, 1811.	Otto, 1867.
John, 1814.	Diakonow, 1867–1868.
Gmelin, 1826.	Strecker, 1869.
Kühn, 1828.	Baeyer, 1868.
Lassaigne, 1830.	Klauss and Kessé, 1867.
Couerbe, 1834.	

The earliest distinctly chemical fact ascertained by research conducted on brain matter seems to have been the presence in it of phosphorus. This was discovered by Hensing, and described by him in a dissertation (Examen chemic. cerebri. Giessen, 1715). The discovery was no doubt made by the methods of Brandt and Kunkel, the discoverers of phosphorus, and was one of the many results of the great impulse which the then marvellous productions of these accomplished apothecaries had given to the study of chemistry in the principal European countries. Later in the same century we find Spielmann (Mister. chemiæ Arg. 1766, p. 204) examining the ash of the brain, and discovering in it particles which were attracted by the magnet. Towards the end of the century destructive distillation, which had been for a long period almost the only chemical operation applied to organic, particularly animal, matters, was less frequently used. It had led to the discovery of phosphorus, and of the universal presence of mineral and salty particles in organized beings and all their hard and soft parts and fluids, particularly to the discovery of iron as an essential constituent of the red particles of the blood (Menghini). But its powers for discovery were long exhausted, and other reagents, particularly of the class of the acids, were applied to organic, and amongst them brain matters. Thus we learn from Soemmering's Hirnlehre, p. 81, that Mönch applied nitric acid to brain marrow, and obtained, as a product of its action, oxalic acid.

Hensing finds phosphorus, 1715.

Spielmann analyses ash, 1766.

Mönch obtains oxalic by nitric acid from brains

(See for above quotations the notes of John to the translation of Vauquelin's research (to be cited below) in Schweigger, 8. (1813) 431).

Vauquelin, who gave a history of the chemical labours which had before him been directed upon the brain, was not acquainted with any of the authors just quoted, and gives, as the earliest observation concerning chemical features of the brain, that of Gurman, relating to the prolonged conservation of brain-matter in the skulls of corpses.

Gurman; conservation of brain in corpses.

A more detailed appreciation of the chemical peculiarities of the brain appears already in the note of Burrhus, also quoted by Vauquelin, who had compared its ingredients to some oil and to spermaceti.

Burrhus compares brain to an oil and to spermaceti.

The great rise of chemistry in France towards the end of the last century inspired the celebrated physician Thouret, the contemporary and friend of Lavoisier and of Vauquelin, with the desire to institute some chemical researches on the human body, and he was led to investigate the brain by the curiosity which at that time existed in Paris, by the observation that of the remains of dead bodies which had been exhumed from the cemetery of the Saints Innocents, many parts, particularly the brains, were in a remarkable state of preservation, although the bodies had been buried so many years, that under ordinary conditions they would have been completely disintegrated. While other inquirers applied themselves to the substance which then received the name of "adipocire," Thouret (Journ. de Phys. 38 (1790) 329) made some inquiries on the brains which led him to the conclusion that they consisted of *a soap*, of which a *fatty*

Thouret, 1790.

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matter, similar to, if not identical with, spermaceti, and a *fixed alkali*, were the proximate constituents.

Supposed spermaceti.

Fourcroy, 1793.

Mineral phosphates.

About this time Fourcroy (Ann. de Chim. 16 (1793) 282) instituted some researches on the brains of calves, sheep, and of man. He showed that the brain contained, as chief ingredients, an *albuminous* and a peculiar *animal* matter, and a small quantity of *mineral* salts, namely, the *phosphates of ammonia, soda, and lime*, but no fixed alkali united with fatty bodies after the manner of soaps, as Thouret had stated (regarding the brains from the cemetery, which do not appear to be fair objects of a comparison in which identity of material is assumed as the basis of the criticism. Th.). Fourcroy subjected brain matter to the action of heat, of water, of sulphuric acid, of dilute nitric acid, and of alcohol. With boiling alcohol he extracted a matter which, on cooling of the solution, was deposited in brilliant plates of a yellowish white colour. This was probably the same substance as that which Burrhus and Thouret had considered analogous to spermaceti, and which, from the description, we easily recognise as the substance now termed cholesterine. Fourcroy showed its differences from spermaceti, and declared its peculiarity, but without giving it any name. It is singular that Fourcroy, though the author of these experiments, which Vauquelin praises as the most complete and successful ever instituted before his own, gave no account whatever of the chemical properties of brain substance in the fourth volume of his work on chemistry, which was published some years after the publication of his essay. (I refer to the English translation, in 4 vols., by R. Heron. London, 1796.)

Alcohol first employed.

Crystals are not spermaceti.

Vauquelin, 1811.

In 1811, Vauquelin (Ann. du Mus. d'Hist. Nat., 1811, p. 212–239: also in Ann. Chim., 81, 37: English translation in Ann. of Philos. 1, 332; German in Schweigger, 8 (1813) 430–460) published a remarkable research on the brain and nerve substance of man and animals.

In order to appreciate fully the great value of this inquiry, we must consider somewhat in detail the proceedings and results of the great animal chemist.

Vauquelin's process.

White matter in scales and flakes.

Human brain was pounded and triturated in a mortar until it presented a homogeneous paste; it was then mixed with five parts of alcohol of 36 degrees, allowed to stand 24 hours, and then heated to ebullition and filtered. The alcohol became greenish, and deposited, on cooling, a white matter, partly in flakes, partly in scales. After standing 12 hours, the alcohol was filtered from the deposit; it had retained its greenish colour, and became milky when mixed with water. This alcohol was next evaporated to one-eighth of its original bulk; it deposited during cooling an oily yellowish and fluid matter, which sank to the bottom of the vessel containing the now yellow fluid. This fluid resembled a solution of gum. The extraction of the brain matter with alcohol was repeated, and the extracts were treated like the first one. The solution had a more bluish colour. (This green colour, it may be at once stated, is partly due to a fluorescent ingredient of the brain, partly to copper, either contained in the brain or imported as an impurity; but the blue colour Vauquelin extracted from his filtering paper. Such is the opinion of Couerbe, and I have myself been obliged to abandon the use, in my brain researches, of the otherwise excellent grey French hand-made filtering paper, because the solution of brain-matter in alcohol extracted from it a blue or violet colouring matter.)

Colour of alcohol explained.

White matter.

Now, although Vauquelin had observed that the first deposit from the hot alcohol extract consisted of a *flocculent* and a *scaly* matter, therefore of two matters differing in their physical appearances, yet this does not appear to have made the necessary impression upon him. He made no attempt to separate these matters, either mechanically or by solvents, but treated the entire deposit as a homogeneous substance. He described it correctly as white and concrete, yet soft and plastic, shining like white silk, and staining paper like grease. He found it fusible by heat, but never so liquid as fat, and assuming a brown colour at a temperature at which fat is not changed. It dissolved in hot alcohol, but left flakes of an *animal matter* undissolved, which he believes to have been held in solution only with the aid of the water primarily contained in the brain. Like all subsequent observers, except Couerbe, he threw this matter aside (Couerbe's cephalote and stearoconote) as if it were an albuminous impurity, and thus missed, like all observers after Couerbe, these most important ingredients. He determined, however, that 20 parts of alcohol of 36 degrees were sufficient to dissolve all that is soluble in one part of white

Stearoconote missed.

matter. Exposed to the sun, the white matter became yellow, a phenomenon which John explains as the effect of incipient oxydation. After repeated digestion in alcohol to separate the last traces of animal matter (stearoconote), a portion was burned in a platinum dish, and left a charcoal containing an acid which precipitated lime-water. He explained this correctly as evidence of the presence of phosphoric acid, which he thought might be contained in the white matter as such, or combined with ammonia, losing its base by heat, though he thought this surmise improbable.

Phosphoric acid in white matter.

Desirous of extracting any phosphate with water, he triturated some white matter with water, and was surprised to find that it formed a sort of emulsion, and remained quite neutral to litmus. Potash evolved no ammonia, even on boiling, and even a quantity of potash which would have dissolved any similar amount of fat, did not effect a solution, and the liquid remained as milky as if water alone had been employed. Thus it was proved that the white matter contained neither phosphoric acid nor ammonic phosphate.

Fusion with potash.

One part of white matter heated with two parts of caustic potash and a little water, did not fuse; on the contrary, it became hard, which could not have occurred if the matter had been fat. After evaporation of the water, the mixture assumed a brown colour, took flame, and exhaled an odour of burned fat, with much soot. The residue was extracted with water, the extract boiled with nitric acid, and the solution then yielded to lime water, calcium phosphate, which when dry weighed one-tenth of the white matter employed. One part of white matter, deflagrated gradually in two parts of fused nitre, yielded by appropriate treatment as much calcium phosphate as the previous operation.

Deflagration with nitre.

Phosphorus in a peculiar form.

From these phenomena Vauquelin concludes that with the white fatty matter of the brain, there is combined a quantity of *phosphorus*, which dissolves in alcohol at the same time as the matter itself. The matter contains neither lime nor magnesia, though they are contained as acid phosphates in the alcoholic mother liquor, together with phosphate of potassium. From these phenomena Vauquelin concludes that in the brain phosphorus is present in the same form as that which he said Fourcroy discovered in the roe of fishes. Judging from the quantity of phosphate of lime obtained, he believes the quantity of phosphorus *to be but small*, and to amount to not above* fifteen thousandths of the wet brain, or to about $7\frac{1}{2}$ per cent. of the dry brain matter.

White matter, a peculiar and new kind of fat.

Vauquelin further says that although this white matter approaches more to the nature of fats than to that of other substances, yet it must not be confounded with ordinary fats. It differs from them by its solubility in alcohol, its crystallisability, its viscosity, its lesser degree of fusibility, and by the black colour which it assumes on fusion. If, therefore, it is desired to range this matter under the class of fats, it must be considered as a peculiar and new kind of fat. Vauquelin evaporated the alcoholic solution from which the white matter had been deposited, in one operation (without, as will be seen to have been done in my experiments, effecting a fractional evaporation, and obtaining one or more intermediate precipitates). Towards the end of the evaporation he observed the formation at the bottom of the fluid of an oily, fluid, yellow matter, which he supposed to result from the "brain moisture." The liquid in the depth of which this oily matter collected, had also a yellow colour, a faintly sweet taste of broth, and showed traces of acidity. As long as the liquid was hot, the matter remained separate, and of a certain consistency; but when the fluid cooled, or on addition of a little cold water, the matter absorbed moisture, lost its translucency, and became diffused in minute flakes so that it could not be separated any longer; it was, therefore, necessary to observe the favourable moment for its separation, and to employ hot water for washing it and separating it from the soluble admixtures. The oily matter was dried at a gentle heat, or in the open air; it was brownish red, had an odour like that, or stronger than that, of brain, and a rancid taste; triturated with cold water it diffused in it, and formed a kind of uniform emulsion, which separated only very slowly. Mineral acids mixed with this emulsion, separated immediately the oily matter in form of white opaque flakes, and the fluid now filtered clear, which it had not done before. From the hydrochloric acid which had been employed to coagulate this emulsion, ammonia afterwards precipitated white light flakes. But when nitric acid had been employed for the same

Oily deposit.

Hot water required to wash and collect it.

Reactions of oily matter.

* Here is a misprint saying $\frac{1}{100}$, which must be wrong from the context.

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purpose, neither ammonia nor lime water produced any precipitate in it. The emulsion was also coagulated by tincture of galls.

The oily matter, from which the water had been decanted, putrified, and spread a stinking odour.

Oily matter putrifies.

With alcohol.

Burned, gave phosphoric acid.

The oily matter was soluble in hot alcohol, a few flakes excepted, which did not amount to one per cent., the greater part was deposited again on cooling; water made the alcohol solution turbid like that of a resin. Exposed to glowing heat the oily matter fused, became black, frothed, and exhaled the odour at first of albuminous, afterwards of fatty burning matter. Burned with potash or nitre, it gave phosphoric acid, like the white matter. It contained neither free phosphoric acid nor phosphates. From 400 grammes of brain matter, Vauquelin obtained three grains of this matter, equal to 0·75 per cent. The oily matter differed from the white matter by its red-brown colour, its lesser consistency, its broth like taste, and a greater tendency to crystallisation. For when hot alcohol was saturated with it it deposited scales or crystals on cooling. Nevertheless, Vauquelin concludes that the oily matter is in the main the same as the white matter, but mixed with a certain amount of animal (albuminous) matter, which could be separated from the fatty part by cold alcohol.

Peculiarities of the oily matter.

Yellow watery mother liquor.

The yellow watery mother liquor which remained when the white and oily matter had been deposited, and all the alcohol evaporated, had an acid reaction, and a sugary and broth-like taste. It was diluted with water, and then treated with lime water, until this reagent produced no longer any precipitate. The precipitate was washed, dried, calcined, dissolved in nitric acid, precipitated by ammonia, and was found to be pure phosphate of lime.

Phosphoric acid removed.

Solution evaporated to dryness.

The filtrate from the lime water precipitate was evaporated to dryness, the residue was reddish brown, semi-transparent, had the same somewhat sweet and gravy-like taste as before, and dissolved in alcohol with facility, leaving some saline matter which effervesced with acids. Exposed to the air it deliquesced; burned in a platinum crucible, it emitted vapours of burning animal matter, with much frothing; it left a charcoal, which by extraction with water and evaporation yielded pure carbonate of potassium. From these reactions Vauquelin concluded that the matter in question was identical with that which Rouelle had formerly termed "soap-like extract of flesh," and to which Thénard had given the name of "osmazome." The brain matter, deprived of its fatty matters, contained albumen and coagulated globules of a membranous substance, the neurilemma. This substance when dry assumed a grey colour, a semi-transparence, and a fracture similar to that of gum-arabic. When put into water it became opaque, swelled up, and softened, and a small part dissolved. In this softened state it dissolved easily in caustic potash by the assistance of heat, and during the solution no ammonia was disengaged. (Difference from caseine of milk.) The potash solution was slightly yellow, and had a weak smell. Acids produced in it a white flocculent precipitate, and disengaged a very fetid odour. Acetate of lead dropped into the potash solution produced a dark brown precipitate, showing the presence of sulphur. (The matters extracted by alcohol from the brain did not contain any sulphur.) By destructive distillation the albumen of the brain yielded carbonate of ammonia in crystals, and a red oil similar to that yielded by common albumen under similar circumstances. By complete combustion it left phosphate of lime and magnesia, but no free phosphoric acid; by deflagration with nitre some sulphuric acid was obtained, confirming the lead and potash test above alluded to. Consequently this matter was identical with albumen, an opinion already enunciated by Fourcroy in the essay above quoted.

Osmazome.

Albumen and neurilemma.

Contains sulphur.

Vauquelin summarised his results as follows:

The brain is composed of—

1. Two fatty matters, which are perhaps identical.
2. Albumen (probably semi-coagulated, and not properly soluble in water).
3. Osmazome.
4. Different salts, amongst them phosphate of lime, phosphate of potash, phosphate of magnesia, and a little common salt.
5. Sulphur.
6. Phosphorus.

He estimated the quantities, as far as such matters could then be estimated, as follows:—

1.	Water, about	80
2.	White fatty matter	4·53
3.	Red fatty matter	0·70
4.	Albumen	7·00
5.	Osmazome	1·12
6.	Phosphorus	1·50
7.	Acid, salts, and sulphur	5·15
		100·00

Putrefaction of brain substance.

In the 10th paragraph of his research Vauquelin gives an account of some experiments on the putrefaction of brain matter in the presence of water. It was found that the albumen decomposed rapidly, but the fatty bodies remained almost entirely unchanged; the osmazome also did not decompose. Ammonia and acetic acid were observed as decomposition products, also some valerianic acid, recognized by the smell of old cheese. During putrefaction the mixture maintained a rose colour for several weeks. As the method of physiolysis, so ably used by Proust for splitting up complex substances into simpler factors, was not sufficiently developed at the time of Vauquelin's brain research he did not obtain results of lasting value in this experiment. Vauquelin also examined the *medulla oblongata* and *spinalis*, and found them analogous in composition to the brain, but they contained much more fatty matter, and less albumen, osmazome, and water. This he supposes to be the reason why the spinal marrow has greater consistence than the brain.

Medulla oblongata and spinalis.

Nerves.

Vauquelin found the nerves of the same nature as the brain, but containing much less fatty matter and much more albumen and neurilemma. They contained moreover common fat, which separated from them when they were treated with boiling alcohol. When the nerves were deprived as much as possible of fatty matter by alcohol they became semi-transparent. When digested in that state in boiling water they did not dissolve, but became white, opaque, and swelled up obviously in consequence of absorbing moisture. The residue of nerve which had been treated with alcohol and water dissolved almost completely in caustic potash. No ammonia was evolved during solution. The potash solution was precipitated in purple flocks by acids, and the supernatant fluid also assumed a purple colour.

Philosophic considerations of Vauquelin.

At the conclusion of his paper Vauquelin asks the question whether it might not be possible to recognise the conditions in which each of the elements composing the brain is present in that organ. At first he questioned whether the albumen was not combined with a portion of the phosphoric acid, and whether its consistence and opacity was not perhaps caused by this combination. However that might be, he is inclined to believe that the albumen is in a state of semi-coagulation, after the manner of caseine in milk becoming sour. He next inquires whether fatty matter, albumen, and osmazome are in some combination with each other in the brain, and is inclined to answer the question affirmatively, at least as regards fatty matters and albumen.

Vauquelin's data are perfectly correct as far as they go; they furnished an excellent basis upon which the more perfect methods of later times might have built a complete analysis of brain matter. But the later analysts were all deficient in that appreciation of the totality of the subject which alone gives power for exhaustive research. With the one remarkable exception of Couerbe they were men of detail, fishing for some chemical object of passing interest and neglecting their predecessors, as well as the physiological philosophy of the important organ upon which they undertook to operate.

John's inquiries.

The analyses of Vauquelin were repeated and confirmed by J. F. John (Chemische Schriften, Vol. 4, nro. 31, p. 228; and Zoo-chemische Tabellen, Tab. 1, A (1814), p. 12); also in Gilbert, Annal. 46 (1814), 329), who examined the cerebral matter of calves, deer, chickens, and crayfish. The observation of phosphorus in the human brain caused him to institute a special research on the brains of calves and oxen, which led him to the conclusion, as he expressed it, "that they did not contain any substantial phosphorus." He meant, no doubt, phosphorus in the metalloid form, as it is met with at the point of

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a lucifer match, and as distinguished from the phosphorus in combination, such as is known to be contained in bones, as phosphate of lime. He found phosphate of ammonia in his extracts, or rather phosphoric acid in one experiment, and ammonia in another, and therefore believed that the phosphoric acid found by Vauquelin was the result of a decomposition of this ammonia phosphate; he thus assumed against Vauquelin the correctness of a surmise which Vauquelin had at first formed himself, but had ultimately dismissed as very improbable. The researches of John are by no means so clear and instructive as those of Vauquelin, though made by the aid of and after them; they contain not a single new fact or development, their direction is throughout governed and consequently confined by the search after the supposed "substantial phophorus," and they consequently miss entirely the fact that in the brain phosphorus is present in *organic combination*.

L. GMELIN diagnoses cholesterine and pulverulent brain fat.

A real progress was effected by the research of LEOPOLD GMELIN (Report f. d. Pharm. 52, 169), and in Zeitschr. f. d. Physiol. von Tiedemann, und Treviranus, 1, 119; also in Gmelin and Tiedemann die Verdauung nach Versuchen, 1826), in consequence of which he distinguished a *pulverulent brain fat*, and a scaly crystalline one, which latter he identified with the *cholesterine* of gall stones. The latter he obtained by boiling brain with alcohol, crystallising the extract, and recrystallising the product with frequent pressing between bibulous paper, until it was free from smeary and tallow-like matter, and represented small crystalline plates. The wax-like brain fat he found to adhere to the bottom of the vessel in which cholesterine crystallised and separated it mechanically. These important results were not equalled by O. B. Kühn's researches (De cholesterino eique similibus pinguedinis corporis humani formis, Diss. Lipsiæ, 1828); (Extract in Kastner's Arch. f. Naturlehre, 13 (1828), 337), which had a retrograde effect. He separated cholesterine from Vauquelin's white matter by ether, and obtained it mixed with phosphorized bodies, but believing his product to be a new body and neglecting to apply Gmelin's process of purification, or unsuccessful in its application, he termed it *cerebrin*, distinguished it from the cholesterine of gall stones and controverted Gmelin, as we now know, erroneously. Kühn also obtained the pulverulent brain fat as the matter insoluble or least soluble in ether, and termed it *myelokon* (marrow powder). He also seems to have first noticed the brown matter which was afterwards described by Couerbe as céphalote.

Kühn's researches: myelokon and cerebrine.

LASSAIGNE 1830, on retina and optic nerves.

In 1830 LASSAIGNE (Ann. Chim. 45, 215; see also Journ. de Chim. Méd. 2nde serie, 1, 344; Compt. Rend. 9, 703; 11, 763) gave a chemical analysis of the retina and optic nerves. He found their constituents identical in kind, but the retina contained more water than the optic nerve.

The constituents of the retina were in 100 parts:—

Water - - - - -	92·90
Saponifiable fat and cerebrin - -	0·85
Albumen - - - - -	6·25

The optic nerve yielded in 100 parts:—

Water - - - - -	70·36
Cerebrin - - - - -	4·40
Osmazome and common salt - -	0·42
Gelatine - - - - -	2·75

Couerbe, 34.

The most extensive and after that of Vauquelin most fruitful research on the chemistry of the brain was published in 1834 by J. P. COUERBE. It was presented by him to the Academy of Sciences of Paris, on June 30, 1834; but meeting with little favour from that body it was published in Ann. Chim. 2nde serie, 56, 160–193. Couerbe experienced the strongest critical opposition on the part of Frémy, as we shall see below, where it will also appear what a great amount of truth there was in Couerbe's work, and how little in that of his opponent. After the publication of Frémy's own research Couerbe again endeavoured to urge his claim to consideration (Nouvelles considerations sur le cerveau. Compt. Rend. 10 (1840), 974), and defended himself against the criticisms of the apparently weightier chemist. The Academy appointed a committee of reporters, comprising Messrs. Chevreul, Dumas, and Pelouze, and this committee, swayed by a prominent error in Couerbe's statements, an

error which might have easily been eliminated from the mass of prosperous truth, namely, the alleged finding of sulphur as a constituent of brain fats, rejected Couerbe's appeal, on nearly this argument, that as Couerbe's statement of the presence of sulphur had been disproved by Frémy, therefore the whole of his researches were of no value.

Couerbe announced that he had isolated from the brain of man the following immediate principles :—

1. A yellow pulverulent fat = Stéaroconote.
2. A yellow elastic fat = Céphalote.
3. A yellowish red oil = Éléencéphol.
4. The white fatty matter of Vauquelin = Cérébrote.
5. Cholestérine.

For the isolation of these matters he proceeded in the following manner. He washed the brain, freed from its membranes, with cold water, to deprive it as much as possible of blood. He then reduced it to a pulp in a mortar, and macerated it in cold ether. The first portion of ether removed little except water. Four successive macerations were requisite to deprive the brain of everything which the ether was capable of dissolving. The ether was now distilled off, and the residue was dried in a capsule, and was found to be a white fatty substance, partly amorphous, partly granular. Almost the whole of this residue (when the brain came from a healthy person) consisted of *cérébrote*, but when the brain was that of an insane person, the cérébrote was combined (mixed) with some other substances. This residue Couerbe termed "product " of the ether treatment A."

The brain matter thus extracted with and insoluble in ether was treated with boiling alcohol of 40° strength, and filtered hot, and this treatment was repeated until the solutions gave no longer any precipitate on cooling, this being to him the signal that the brain matters were exhausted of all matters soluble in boiling alcohol. The fibrous residue he termed névrilème, and did not investigate any further.

(Several authors, amongst them Thomson—chemistry of animal bodies—omit all notice of this alcohol treatment, and state that in repeating the researches of Couerbe they could not find several of the bodies mentioned by him. This omission may perhaps explain the futility of their experiments, as well as of their criticisms).

Deposits from boiling alcohol. The alcoholic solutions were cooled, decanted, and filtered, and the deposits were collected. They were washed with cold ether, which removed *cholesterine* and left on the filter *cérébrote*. This latter he declares to have been the main ingredient of Vauquelin's white matter, and points out that as Vauquelin did not employ ether either before extraction of the brain with alcohol or in the purification of the white matter, he must have had cérébrote mixed with a large bulk of cholesterine.

Second deposit from concentrated alcohol extract. The alcohol in which the white powder had been precipitated was further evaporated, in order to obtain a second deposit of this white matter, which continued to fall down, accompanied, however, by other fats soluble in ether.

Semi-fluid deposits. Towards the end of the evaporation a semi-fluid matter was seen to deposit, which was no longer the same as the white matter of the previous deposits. It dissolved in ether, and was deposited in an oily state by the evaporation of the ether. This matter, already noticed by Vauquelin, Couerbe termed *éléencéphol*. Thus it appears that, as Couerbe himself stated, his alcohol extraction, following the ether extraction, yielded him the substances obtained by Vauquelin. But Vauquelin erroneously held the oily matter to be identical with the white matter, and differing from it only by being less pure. Couerbe established the peculiarity of this matter, as will appear lower down.

Treatment of the ether extract according to whether more or less cérébrote is present. The extract A obtained by ether from brain previous to the alcohol treatment was subjected to the following processes. It was, as already stated, evaporated to dryness in a capsule, and then again treated with a *little* ether. This was of uncertain effect, for sometimes the entire residue dissolved again in the ether (in the case, namely, in which the ether had taken up but little cérébrote, and the ether was warmer), and then ether was unavailing to effect any further separation, and was again driven off by heat. Sometimes, however (in the case, perhaps, in which the ether had taken up much cérébrote, or the ether was cold), the operation of treating the residue with little ether left a white

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powder, undissolved cérébrote, which was separated by the filter. The solution also was again freed from ether by evaporation, and the anomaly of excess of cérébrote being removed, the ether extract residues were now uniform, and all subjected to the following treatment.

Alcohol treatment of ether extract residues.

They were boiled with alcohol, which dissolved all the cérébrote (as much, namely, as had been dissolved even in the small quantity of ether) and two other fatty bodies (cholesterine and another to be identified), and left undissolved a *solid brown substance* resembling wax. This brown substance is a mixture of two bodies; one, the greater in quantity, is soluble in ether, and remains, on evaporation of the ether, as a fawn-coloured substance which cannot be powdered—*céphalote*. The part which is not dissolved by ether remains as a brown powder—*stéaroconote*.

Céphalote.

Stéaroconote.

Cholesterin.

The (hot) alcoholic solution, containing cérébrote and two other fatty bodies, is filtered (hot) through animal charcoal, and then left to itself. White fatty crystals are deposited, and an additional quantity of them is obtained by concentrating the liquid. These crystals are a mixture of cérébrote and cholesterin. After collection on a linen filter they are separated by ether, which dissolves the cholesterin and leaves the cérebrote in a pure state. The cholesterin is deposited on evaporation of the ether.

Éléencéphol.

When the alcoholic liquid which has deposited the crystals of cérébrote and cholesterin is further evaporated, *a red oily matter* begins to appear, together with further crystals of cérébote and cholesterine. To obtain this oil, termed éléencéphol, in a separate state, the mixture of liquid, oil, and crystals is put into a linen cloth and squeezed; the alcohol with the oil passes through the cloth, while the crystals remain upon the cloth. Couerbe then added to the muddy alcoholic liquid a little ether, which dissolved the oil and rendered the liquid transparent. He then set the solution aside, whereupon the oil gradually subsided, while the crystalline matter remained dissolved in the alcohol and ether mixture. The oil was ultimately separated by filtration.

The cérebrote of Couerbe is sufficiently characterized as the pulverulent brain fat, insoluble in water and in ether, easily soluble in boiling alcohol, and little soluble in cold alcohol, properties upon which its extraction is based. It is infusible, and does not cause greasy spots on paper. It is not saponified by either caustic, soda, or potash. Thus far the description of cérébrote by Couerbe is quite correct. By elementary analysis Couerbe obtained $^{\circ}/_{\circ}$:

C	67·878
H	11·100
N	3·399
S	2·138
P	2·332
O	13·213

No sulphur had been found by Vauquelin, and of this Couerbe was aware. Frémy and all subsequent observers failed in finding sulphur in these peculiar brain matters, and the reporters of the Academy rejected Couerbe's research upon the ground of this erroneous statement regarding sulphur. The method employed for the separation of the sulphuric acid was that of Berthier, with baryta. The brain matters themselves were not deflagrated with nitre, but boiled with nitric acid. Perhaps the inquirer unfortunately employed impure nitric acid, containing some sulphuric. This appears the more probable, as in all the other analyses (also made with nitric acid) of céphalote, stéaroconote, and éléencéphol he also obtained sulphur, and, what is remarkable, in all nearly the same per-centage.

	Cérébrote.	Céphalote.	Stéaroconote.	Éléencéphol.
Sulphur	2·138	1·959	2·030	same as céphalote.

Frémy's critique of Couerbe.

Frémy, in his memoir quoted below, criticised the observations of Couerbe, and accounted for the sulphur as due to an admixture of albuminous matter. This is entirely inadmissible, as pure albumen does not contain as much sulphur as was here apparently found in a body entirely soluble in hot alcohol. Frémy also stated that the cérébrote, on combustion with nitre, always left him a lime salt, and from this (as will be seen, erroneously) concludes that the body was an acid. He sums up by declaring cérébrote to have been a mixture of cerebric

acid, cerebrate of lime, and albuminous matter, and thus increased the obscurity under which Couerbe, by a singular want of caution regarding his analytical reagents, had left his new and important discovery of cérébrote.

Characters of céphalote.

The céphalote of Couerbe is equally well characterised; solid, brownish, insoluble in alcohol and water, soluble in 25 parts of cold ether; becomes soft by heat, but not fluid; cold, it is elastic and viscous; in boiling alcohol soluble only in inappreciable traces. Destroyed by sulphuric and nitric acid, saponified by caustic alkalies, yielding colourless fatty acids. Thus far this is again in the main a correct description. Elementary composition $^{\circ}/_{\circ}$ =

C	66·362
H	10·034
N	3·250
P	2·544
S	1·959
O	15·851

The phosphorus in this substance was less variable than in cérébrote, an observation which future developments will fully explain. Of this céphalote Frémy asserts that it was a mixture of cerebrate of lime, or soda, with traces of albumen and oleophosphoric acid. But this is entirely erroneous. The céphalote of Couerbe was a mixture of two immediate principles and of their salts. The impurities were cerebrine, and a little cholesterine; the assumption of the presence in it of albumen is still less permissible than in the case of cérébrote.

Stéaroconote.

The Stéaroconote was a powdery, greasy matter, whence the name (στεαρ, solid fat; κονις, powder, derivation similar to Kühn's meyelokon). It is yellowish, infusible, not soluble in either water, alcohol, or ether, even when they are boiling. Yet it has been originally extracted by ether from brain matter, as Couerbe supposes, by reason of the quantity employed, and the combination with all the other matters. It is easily soluble in essential and fatty oils. It dissolves in nitric acid on boiling, and reappears as a white acid fat, soluble in hot alcohol, and crystallising from it in scales similar to margaric acid. Its elementary composition $^{\circ}/_{\circ}$ =

C	59·832
H	9·246
N	9·352
P	2·420
S	2·030
O	17·120

We are struck by the lowness of the carbon as compared to cérébrote, and the reverse bearing of the nitrogen, the more so as we shall below see the easy relation in which this matter or its essence stands to the essence of cérébrote. I have obtained this stéaroconote in every operation upon the human brain, with all the characters given above, excepting the colour and precise elementary composition. I must therefore declare as entirely unfounded the assertion of Frémy, that stéaroconote was mainly composed of the albuminous matter of the brain. Equally unfounded is the assertion of Frémy that the éléencéphol was a mixture of oleine, oleophosphoric acid, cerebric acid, and cholesterin. There is no olein whatever present; the oleophosphoric acid of Frémy is, as will be shown, after Gobley, more problematical than any of Couerbe's principles; and though we must admit the éléencephol to have been impure, yet the peculiarity of its essence cannot for one moment be doubted by those who have produced and treated it.

Eléencéphol.

Éléencéphol is liquid, reddish, of a disagreeable taste, soluble in all proportions in ether, essential and fatty oils. In alcohol it is soluble by aid of heat, but much less easily than in ether. Otherwise it has few remarkable properties, and in composition it closely resembles céphalote, so that Couerbe considers it as isomeric with this body. This description is in the main correct, though less complete than that given by Vauquelin.

It must not be forgotten that Couerbe was the first chemist who applied quantitative elementary analysis to the brain matter he had extracted. The methods of analysing were at that time by no means as perfect as at present; though he had Liebig's carbonic acid bulbs, he had to use a less perfect method

[illegible] The science [illegible]

[illegible] This [illegible] substance [illegible] soluble in ether and [illegible] substance which [illegible] is not dissolved by ether [illegible]

[illegible] and two other fatty bodies, [illegible] and then left to itself. White fatty crystals are [illegible] an additional quantity of them is obtained by [illegible] the liquid. These crystals are a mixture of cérébrote and cholesterine. After collection on a linen filter they are separated by ether, which dissolves the cholesterine and leaves the cérébrote in a pure state. The cholesterine is obtained on evaporation of the ether.

When the alcoholic liquid which has deposited the crystals of cérébrote and cholesterine is further evaporated, a red oily matter begins to appear, together with further crystals of cérébrote and cholesterine. To obtain this oil, termed [illegible], in a separate state, the mixture of liquid, oil, and crystals is put into a linen cloth and squeezed; the alcohol with the oil passes through the cloth, while the crystals remain upon the cloth. Couerbe then added to the [illegible] a little ether, which dissolved the oil and rendered the [illegible] transparent. He then set the solution aside, whereupon the oil gradually [illegible], while the crystalline matter remained dissolved in the alcoholic and ether mixture. The oil was ultimately separated by filtration.

The cérébrote of Couerbe is sufficiently characterised as the pulverulent brain [illegible], insoluble in water and in ether, easily soluble in boiling alcohol, and little soluble in cold alcohol, properties upon which its extraction is based. It is [illegible], and does not make greasy spots on paper. It is not saponified by [illegible], soda, or potash. Thus far the description of cérébrote by Couerbe is quite correct. By elementary analysis Couerbe obtained [illegible]:

C	67·[illegible]
H	11·[illegible]
N	3·[illegible]
S	2·[illegible]
P	2·[illegible]
O	13·[illegible]

No sulphur had been found by Vauquelin, and of this Couerbe was aware. [illegible] and all subsequent observers failed in finding sulphur in these peculiar brain matters, and the reporters of the Academy rejected Couerbe's research [illegible] the ground of this erroneous statement regarding sulphur. The method employed for the separation of the sulphuric acid was that of Berthier, with baryta. The brain matters themselves were not deflagrated with nitre, but [illegible] with nitric acid. Perhaps the inquirer unfortunately employed impure nitric acid, containing some sulphuric. This appears the more probable, as in all the other analyses (also made with nitric acid) of cephalote [illegible] and [illegible] he also obtained sulphur, and, what is [illegible] all nearly the same percentage.

	Cérébrote.	Cephalote.	[illegible]
Sulphur	2·[illegible]	1·[illegible]	2·[illegible]

[illegible] in his memoir quoted [illegible] and accounted for the sulphur as [illegible] This is entirely [illegible] it was [illegible] also stated that [illegible] salt, and [illegible] an acid. [illegible]

acid, cerebrate of lime, and albuminous matter, and thus increase obscurity under which Couerbe, by a singular want of caution analytical reagents, had left his new and important discovery

The céphalote of Couerbe is equally well characterised: insoluble in alcohol and water, soluble in 25 parts of cold by heat, but not fluid; cold, it is elastic and viscous: only in inappreciable traces. Destroyed by sulphuric and by caustic alkalies, yielding colourless fatty acids. Thus the main a correct description. Elementary composition =

C	66·362
H	10·034
N	3·250
P	2·544
S	1·959
O	15·851

The phosphorus in this substance was less observation which future developments will Frémy asserts that it was a mixture of cerebrate albumen and oleophosphoric acid. But céphalote of Couerbe was a mixture of salts. The impurities were cerebrine, and of the presence in it of albumen is still less cérébrote.

The Stéaroconote was a powdery, greasy matter fat; *κονις*, powder, derivation similar to Kühn infusible, not soluble in either water, alcohol boiling. Yet it has been originally extracted Couerbe supposes, by reason of the with all the other matters. It is easily dissolves in nitric acid on boiling, and reappears hot alcohol, and crystallising from scarcely elementary composition % =

We are struck by the the reverse bearing of the relation in which this I have obtained this with all the characters tary composition. assertion of Frémy, that matter of the brain. éléencéphol was a cholesterin. Frémy is, as will be Couerbe's principles impure, yet the those who

Cerebrates.

...omic weight of ... free acid had

... quantity that the ... sult to be highly

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for the determination of nitrogen (in a vacuum produced by Gay Lussac's pump); while it is just possible, though hardly probable, that he could obtain all the phosphorus present in his substances by mere treatment with nitric acid.

Cholesterine.

Of cholesterine Couerbe stated that, contrary to all previous authors who had stated that this body was a morbid product in the brain, he had found it regularly in healthy brains, and therefore considered it a normal ingredient, which moreover was present in large quantity. He determined correctly its elementary composition, and other properties, after Kühn and Chevreul.

C	84·895
H	12·099
O	3·006 %

The speculative part of Couerbe's paper has far less value than the pragmatic descriptive one. He gives empiric formulæ for his substances, from which he omits sulphur and phosphorus, and enters into a consideration of substances similarly constituted. He concludes his essay with some philosophic considerations, which had more value for the time in which they were written than for the present period, but are still worthy of perusal by all admirers of striving minds.

It is surprising in the extreme that these researches of Couerbe should not have been followed up and enlarged, that on the contrary they should have been controverted, denied, and almost ridiculed.

Thomson, Chem. of Anim. Bodies (1843), p. 271, states that he attempted to extract the various matters described by Couerbe from the human brain, but, with the exception of cérébrote and cholesterine, unsuccessfully. Thénard in his Traité de Chim. also criticised these observations in the spirit of the judgment of the academy. While the physiologists of the first 20 years following their publication were yet conscientious enough to quote them, many of the later ones just mentioned the substances as chimerical, and then substituted their own much less perfect experiments and views.

Frémy's research, 1841.

This was mainly caused by a publication of Frémy's (Ann. Chim. 2, 463; also Journ. de Pharm. 27, 453), which was thus summarised by Thomson, l.c.p. 270—" Frémy confirmed the existence of cérébrote and cholesterine " discovered by Vauquelin and Couerbe, but showed that cérébrote when pure " possesses acid properties, and on that account distinguished it by the name " of *cerebric acid*. He found also in the brain an acid, to which he gave the " name of *oleophosphoric*, which he considers as a compound of oleine and " phosphoric acid. He extracted also oleic and margaric acid from brain, and " agrees with Vauquelin in admitting the presence of a considerable quantity " of albuminous matter."

Frémy's proceeding.

Frémy cut the brain into small pieces, heated it repeatedly with boiling alcohol, and left it for some days in alcohol, in order to withdraw as much of the water as possible. Thus deprived of its elasticity, the brain was subjected to the action of a press. It was then quickly pounded in a mortar, and treated with ether. This operation was effected with the least possible exposure to air, in order to prevent the brain from becoming moist again.

The ether extracts, one cold, the other hot, on distillation left a viscous residue, which Frémy termed " ethereal product." After extraction with ether, the brain matter was boiled with alcohol. The alcoholic decoctions deposited the peculiar matter discovered by Vauquelin, containing phosphorus. After this deposition the alcohol contained only fatty matters in solution, and presented an acid reaction, due to the presence of phosphoric acid.

Frémy thus extracted from the brain :

1. A white matter, which he named cerebric acid, and identified to some extent with the white matter of Vauquelin and the cérébrote of Couerbe.
2. Cholesterine.
3. A particular fatty acid, *oleophosphoric acid.*
4. Traces of oleine, margarine, and fatty acids. Frémy stated that these matters were not always contained in the brain in a free state. Cerebric acid according to him was frequently combined with soda or phosphate of lime. The *oleophosphoric* acid he assumed to be ordinarily in the state of soda salt.

Special proceedings for preparing cerebric acid.

To extract cerebric acid Frémy treated the residue from the ether extractions (" ethereal products ") with a great quantity of ether. He precipitated thereby

a white matter, which he isolated by decantation, and which on exposure to air transformed itself into a waxy, greasy mass. This precipitate contained cerebric acid, often combined with phosphate of lime, or with soda; oleophosphoric acid, combined with phosphate of lime or soda; and albumen, carried hither by the impurities. The precipitate was dissolved in boiling absolute alcohol, which had been made slightly acid by sulphuric acid. Sulphates of lime and soda remained suspended, mixed with the albumen, and were removed by filtration. Cerebric and oleophosphoric acids were in solution, and deposited on cooling. The deposit was washed with cold ether, which dissolved the oleophosphoric acid, and left the cerebric acid behind. The cerebric acid was then dissolved in boiling ether, and repeatedly recrystallised.

Properties of cerebric acid.

The cerebric acid thus purified was white, and appeared in the shape of little crystalline granules; it was entirely soluble in boiling alcohol, nearly insoluble in cold ether, more soluble in boiling ether. It had the remarkable property of swelling like starch in hot water, but appeared to be insoluble in this fluid. It fused at higher temperatures and then was easily decomposed. It burned under evolution of a peculiar smell, leaving a quantity of charcoal, which burned with difficulty, and was sensibly acid. Sulphuric acid made it black; nitric acid decomposed it, only very slowly. Burned with nitre and soda carbonate the cerebric acid never yielded potassium sulphate, but always a quantity of phosphate, which could be determined. Thus the body was free from sulphur, as had been stated by Vauquelin. The cerebric acid contained nitrogen, for on being heated with an excess of potassa it evolved ammonia. The elementary analyses of Frémy were made by the ordinary methods. The phosphorus he determined as baryum phosphate avoiding the presence of carbonate, or as iron phosphate, according to the process of Berthier.

The analyses yielded him the following results:—

C	66·7
H	10·6
N	2·3
P	0·9
O	19·5
	100·0

Cerebric acid may be combined with all bases, and must be considered as a true acid. It differs from the ordinary organic acids by its insolubility in water and by its other physical properties. Its solubility in alcohol and boiling ether approach it to the fatty acids, but its high fusing point, and its affinity for water, by which it is hydrated, remove it much from the fatty acids.

Cerebrates.

When cerebric acid is heated with dilute solutions of potash, soda, or ammonia, it does not dissolve, but combines with each of these bases. The compounds may also be obtained by mixing any of these bases with an alcoholic solution of cerebric acid; a precipitate almost insoluble in alcohol, which immediately ensues, must be considered as a compound of cerebric acid and the base employed. Lime, baryta, and strontia, combine directly with cerebric acid, and deprive it of its peculiarity to swell and form emulsion with water.

Cerebrate of baryum was prepared by boiling cerebric acid in water, in order to hydrate it; an excess of baryta water was then thrown into the fluid; the mixture was then heated to boiling for some time, carbonic acid being carefully excluded. A white flaky insoluble precipitate was thus obtained, which dried with ordinary precautions showed the following composition:—

Salt	-	0·141
Baryta	-	0·011
Cerebric acid		0·130

corresponding to 7·8 per cent. of baryta.

This compound did not enable Frémy to calculate the atomic weight of cerebric acid any more than his elementary analyses of the free acid had enabled him to calculate even an empirical formula.

The analysis was unreliable as being made on so small a quantity that the mere removal of phosphoric acid must have caused the result to be highly inaccurate.

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Attempted decomposition of cerebric acid.

When Frémy had recognized that acid solvents decomposed oleophosphoric acid completely into oleine and phosphoric acid, he tried to effect a similar decomposition upon cerebric acid, hoping to split it up into a solid fatty body and phosphoric acid. He foresaw that the decomposition would have to be complicated, on account of the nitrogen present. But his experiments remained unsuccessful, because the cerebric acid was never completely decomposed, and always retained phosphorus.

Oleophosphoric acid.

The ether which had been used for the precipitation of the cerebric acid from the ether product contains in solution a viscous matter, which is in part oleophosphoric acid, often combined with soda. In order to obtain free oleophosphoric acid it is necessary to decompose the salt with an acid, and to dissolve the acid in boiling alcohol, from which on cooling it is reprecipitated. The acid can be freed from some oleine which is always admixed by absolute alcohol, and from cholesterin by ether. Nevertheless, Frémy did not succeed in preparing the oleophosphoric acid in a state of entire purity, as it always contained cholesterin and cerebric acid.

Not obtained pure.

Colour.

The oleophosphoric acid is ordinarily coloured yellow like oleine. It is insoluble in water, and swells a little when put in boiling water, a phenomenon which Frémy supposes to arise from the presence of cerebric acid. It has a viscous consistence. It is insoluble in cold alcohol, but dissolves easily in boiling alcohol; it is soluble in ether. When put in contact with potash, soda, or ammonia, it immediately yields soap-like compounds, which have again all the properties of the matter extracted from the brain substance by the first ether treatment. With the other bases it forms insoluble compounds. It burns in air, and leaves a strongly acid charcoal, in which the presence of phosphoric acid can be recognised.

Soluble in, or insoluble in, alcohol, &c.

Salts: alkaline, earthy.

Burns: leaves phosphoric acid.

Oleophosphoric acid is decomposed yielding oleine and phosphoric acid.

The liquid greasy substances obtained from the brain do not always show the same properties. Sometimes they are liquid like oleine, at others they are on the contrary viscous. In come cases they contain phosphorus, in others not any. This arises from the decomposition of the oleophosphoric acid which can be engendered artificially. When it is boiled for a long time in water or alcohol, it gradually loses its viscosity, and is transformed into a fluid oil, oleine, almost pure. The liquid has a strongly acid reaction, due to the newly-formed phosphoric acid.

Decomposition by boiling, particularly in acid fluids.

This decomposition, which is always long and incomplete when oleophosphoric acid is boiled in pure alcohol or water, may be effected very quickly by making the liquid slightly acid. The decomposition also takes place at the ordinary temperature, but is then very slow. The air does not seem to take any part in this change.

The oleophosphoric acid is not a mixture.

Yields oleine by decomposition.

It is possible to prove by several proceedings that the oleophosphoric acid if not a mere mixture of oleine and phosphoric acid. Oleine is soluble in cold absolute alcohol, while oleophosphoric acid is entirely insoluble in it. If then an oleophosphoric acid, which is thus insoluble, is decomposed by boiling with acidified water, it is found to have changed its nature after some time, and that the oily matter produced is now soluble in cold alcohol. It has become oleine, which burns on platinum foil without leaving any carbonaceous residue, while the oleophosphoric acid always leaves a strongly acid charcoal.

Oleophosphoric acid decomposed by putrefaction.

The oleophosphoric acid is decomposed under the influence of putrefying animal matter in the same manner as by boiling with acids. Fresh brains always contain oleophosphoric acid, while brains which had been left for some time, and which began to decompose, yielded much oleine and free phosphoric acid.

No elementary analyses.

Frémy did not publish any analyses of his oleophosphoric acid, as he was convinced that those which he had made had been performed upon impure products.

Easily attacked by fuming nitric acid.

Amount of phosphorus.

The oleophosphoric acid may be easily attacked by fuming nitric acid; this reagent produces phosphoric acid, which remains in solution, and a fatty acid, which floats upon the fluid. Frémy in determining by this process the phosphorus contained in the oleophosphoric acid, found in several analyses, quantities varying between 1·9 and 2·0 %.

Alkalies split up the oleophosphoric acid.

Alkalies in excess transform the oleophosphoric acid into phosphates, oleates, and glycerine. It has not been possible to form artificially oleophosphoric acid, although a compound of sulphuric acid and oleine is known as artificially producible.

Chevreul in an article in the Dictionnaire des Sciences Naturelles had already expressed the opinion that the fatty matter of the brain could be considered as a compound of oleine and phosphoric acid.

Oleine of the brain.

The brain often contains an oily matter, which has been found by most chemists studying the brain. This, according to Frémy, came from a spontaneous decomposition of the oleophosphoric acid. Frémy showed how the oleine could be obtained in considerable quantity, by decomposing the oleophosphoric acid by means of acidulated alcohol or water. When the acid thus boiled has lost its syrupy consistence, it is transformed into a fluid oil. This is repeatedly washed and then extracted with cold absolute alcohol. This agent dissolves the oleine, and leaves behind the cerebric acid and the cholesterine, which the oleophosphoric acid had held in solution. On evaporating the alcohol oleine is obtained with the following characters: it is fluid, greasy to the touch, coloured yellow, and burns with a white flame without leaving any ash. On elementary analysis:—0·204 grm. gave 0·590 of CO_2 or 79·5 °/$_0$ of carbon, and 0·220 grm. of H_2O, or 11·9 °/$_0$ of hydrogen, leaving for oxygen 8·6 °/$_0$. These proportions are the same as those which Chevreul found for the oleine from human fat; but they are incorrect, trioleine $C_{57}H_{104}O_6$

Mode of obtaining oleine from acid.

Characters of the oleine obtained.

Analysis of oleine.

	requiring		and human oleine yielding	
C	77·37		C	77·5
H	11·76		H	11·5
O	10·87		O	11·0
	100·00			100·0

(Chevreul, Rech. 185 and 244; *see* Gmelin, 17, 87.)

Easily saponified.

The oleine from the brain is easily saponified by alkalies yielding oleates and glycerine. Before subjecting oleine to analysis it is necessary to wash it with alcohol of 34° containing a little potash, in order to dissolve any traces of oleic and margaric acid which it might retain. Frémy considered only such oleine as pure which burned without leaving any acid charcoal, thus showing that, according to Frémy, it did not contain any oleophosphoric acid, and which could be entirely transformed into soap, which soap was completely soluble in water, thus proving the absence of cholesterin. (Soaps dissolve cholesterine.)

Tests of the purity of oleine from the brain.

	Oleic acid $C_{18}H_{34}O_2$ requires	Trioleine $C_{57}H_{104}O_6$	Frémy found
C - -	76·59	77·37	79·50
H - -	12·06	11·76	11·9
O - -	11·35	10·87	8·6

In Frémy's alleged oleine the carbon is therefore 2·2 °/$_0$ too high, and the oxygen 2 °/$_0$ too low, as compared to trioleine; it is therefore not impossible that he had *oleic acid or oleate of ethyle mixed with some cholesterine* in his hands. A mixture of an atom of oleic acid with an atom of cholesterine would yield C = 80·29; H = 12; O = 7·6 °/$_0$ figures which differ from Frémy's analytical results much less than these results differ from the theory of oleine. T.)

Mode of obtaining cholesterine.

Frémy gives the following procedure for the isolation of cholesterine. The first ether extract is boiled with alcohol which has been made strongly alkaline with potash. By this proceeding cerebrate, oleate, and phosphate of potash, glycerine, and cholesterine are produced. The alcohol on cooling deposits the cerebrate and phosphate of potash together with the cholesterine. The deposit is now treated with cold ether, which dissolves all the cholesterine and that only. It is easily purified by crystallisation.

Fatty acids obtained from the brain.

When the ether product is extracted with alcohol of 34° strength made alkaline with ammonia, an ammoniacal salt is obtained, which on its decomposition yields both oleic and margaric acids. The quantity of these acids in the brain is very small, but they can be well identified in a human brain (?) the margaric acid in particular by its brilliant needles fusing at 60° C. The brain changes quickly and soon putrefies. The oleophosphoric acid is soon decomposed into oleine and phosphoric acid. But other matters must be similarly decomposed, for Frémy always found the fatty acids in greater

Fatty acids increase during putrefaction.

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quantity in brains already somewhat decomposed than in fresh ones. He ascribes this decomposing action to the albuminous matter. Frémy puts this experience on a parallel with that of Chevreul made upon the fat of dead bodies. Here also an albuminous matter split up the fat into glycerin and fatty acids, which latter were in combination either with lime or ammonia.

Parallel with adipocere.

A similar experience has been published regarding palm oil by Pelouze and Felix Boudet. It contains a kind of ferment, which can transform it into glycerin and fatty acids.

Palm oil similarly decomposed.

Fatty acids deposited in the brain in disease.

In disease such decomposition can perhaps become very considerable, or continue for a long time in the brain. Felix Boudet examined a concretion from the brain of a fœtus, and found it to contain margaric acid fusing at 60°.

Albuminous matter.

A certain quantity of albuminous matter passes into the ethereal extract by means of the fatty matters. It is left undissolved by absolute alcohol, mixed with a little acid. It has the characters of albumen, and contains sulphur (probably also stearoconote).

Softening of the brain.

Frémy found that in softening of the brain the fatty matters underwent the same decomposition which the oleophosphoric acid exhibits when it is in contact with a decomposing animal matter out of the body. He has seen, he says, that the modification which brain matter suffered is due to a veritable putrefaction, which, in acting upon the albuminous matter, destroys its consistence and changes it profoundly.

Differences between white and grey matter.

Frémy stated that the greasy matters were almost always entirely contained in the white matter, and that the grey matter contained but traces of them.

When he had extracted all the greasy matters from the white matter he obtained a residue which presented chemical analogies to the grey matter, but he did not state in what these analogies consisted.

The brains of animals.

The brains of animals contain the same substances as the human brain, but in perhaps different proportions. Thus, upon the same amount of fatty matter, the brain of man contained more cholesterin than the brain of a dog.

Brain fats in the blood.

The analyses of the human brain at different ages yielded no positive results.

Brain fats in other organs.

Chevreul had already found in the blood peculiar fats ordinarily met with in the brain. Cholesterin was found in the blood by Felix Boudet.

All organs containing nerves will probably yield brain acids and fats if, as is likely, nerves have the same chemical constitution as the brain. The circumstance that the liver could secrete so much cholesterin caused Frémy to search for brain acids and fats in it, and he succeeded in extracting oleophosphoric and cerebric acids from it.

GOBLEY's researches on yelks.

The researches of GOBLEY which were destined ultimately to throw much light on the nature of brain matter, were begun upon the yelks of hens' eggs (Rech. Chimiques sur le Jaune d'Œuf. Journ. de Pharm. et de Chim. 9 (1846), 1, 81, 161. He showed that they contained water and an albuminous matter,

Vitelline, oleine and margarine.

which latter he, in accordance with precedent, termed vitelline. He further extracted oleine and margarine, as had been done before, by pressing the coagulated and dried yelks, and by exhausting them with ether; but he found this important difference, that whereas the yelk oil obtained by pressure was a mixture of oleine and margarine purely, which when warm easily filtered through paper, the oil obtained by the intervention of ether did not so filter, but left behind a considerable infusible residue, to which he gave the

Viscous matter.

name of *viscous matter*. This matter remains in the yelk cake when the oil is expressed, and can be extracted by ether afterwards. The quantity of fatty oil obtained from dry yelk was in the mean 21 per cent. It contained only cholesterine and colouring matters, and was free from sulphur and phosphorus. The cholesterine, first discovered in yelks by Lecanu, he further studied and

Cholesterine and its fusing point.

identified by elementary analyses. He also stated that the fusing point of yelk cholesterine, which Lecanu had fixed at 145°, while Chevreul had found biliary cholesterine to fuse at 137°, was not actually different from the latter, and claimed that Chevreul had stated the temperature of the moment of consolidation, whereas Lecanu had given that of fluidification.

Particulars of viscous matter.

Of the viscous matter, Gobley says that it had been observed by John, who pronounced it to be not of the nature of a fat. It is specially interesting as containing the phosphorus, which remains in the form of phosphoric acid after combustion. It distributes itself in water, and forms with it a kind of emulsion, soluble in ether and alcohol in the cold, but when treated with

Components of viscous matter.

alcohol leaves a deposit of oleine and margarine. Gobley believed it to be

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Chemolysis of viscous matter by acids.

constituted of a mixture of oleic acid, margaric acid, and a particular acid containing phosphorus, all combined with ammonia, and forming a true soap; this soap he supposed to be, so to say, surrounded and enveloped by an organic nitrogenised matter, differing from vitelline. He chemolysed the viscous matter by heating it in water, with four times its weight of hydrochloric acid, and obtained an oily matter on the top, an intermediate flaky substance, and a liquid. The oily matter was composed of oleic and margaric acid, with cholesterine and neutral fats in small quantity, free from phosphorus. On solution in ether and filtration it left the greyish flakes on the filter. The acid solution, freed to some extent from hydrochloric acid by evaporation, and then diluted with water, gave a precipitate with neutral lead acetate, which contained all the phosphorus. The filtrate treated with sulphuric acid gave on evaporation a residue which contained ammonium sulphate. By caustic alkalies the same chemolytic products were obtained, the fatty acids being separated by acetic acid. The fatty acids were separated by Gusserow's method, treatment of the lead salts with ether, when oleate dissolved and margarate remained. The purified margaric acid fused at 60°, and contained 75·286 °/₀ C, 12·605 °/₀ H, and 12·109 °/₀ O. The oleic acid gave the commonly accepted quantities of elements. 100 parts of dry yelk yielded by this process in the mean 7·226 parts of fatty acids.

Chemolysis of viscous matter by alkalies.

Phosphorised acid.

From the viscous matter, decomposed by long boiling with caustic potash, and neutralised with acetic acid, and freed from liberated fatty acids, the phosphorised acid was precipitated by neutral lead acetate. The precipitate was decomposed by hydrothion and the filtrate concentrated. Some hydrochloric acid was removed by silver oxyde, and the excess of the latter again by hydrothion. Some free phosphoric acid was removed by a slight excess of lime water and filtration. The liquid on evaporation, and while hot, deposited white, brilliant scales, which could be removed and dried. They were more soluble in cold than in hot water; the solution was precipitated by alcohol. By analysis the salt yielded :—

Its lime salt.

	in 100		Theory.
$Ca_2P_2O_7$ (calcium pyrophosphate) -	60·27	60·27	60·66
C - - - - - -	17·07	17·02	17·06
H - - - - - -	3·51	3·48	3·32
O - - - - - -	19·15	19·23	18·95

The acid contained in this salt was found to be phospho-glyceric acid, or as it is now most frequently termed, glycero-phosphoric acid, being the acid previously synthetically prepared by Pelouze, and identified all the more certainly as all Gobley's experiments were made in the laboratory of Pelouze.

Other ingredients.

Gobley further found lactic acid in yelk; then various mineral salts, specially potassic and sodic chloride, potassic sulphate, and calcic and magnesic phosphate. He also distinguished two colouring matters, and meat extract, or osmazome, and concluded his prosperous research by a summary in 12 propositions, embodying the results sketched in the foregoing lines.

Gobley's experiments on brain matters.

In a second memoir (Journ. de Pharm. et Chim. 11 (1847), 409, and 12 (1847), 1) Gobley describes his experiments on the brains of chickens, sheep, and men. He obtained, by proceedings which he did not describe, a viscous matter which had much analogy with that obtained from yelks. When shaken with water and little hydrochloric or sulphuric acid, and warmed on the water bath, it did not decompose, while the matter from eggs had thus been decomposed; but when the viscous matter was boiled for some time with dilute acids it became liquified and gradually floated on the fluid. The greasy layer consisted of oleic acid, margaric acid, cholesterine, and a small quantity of fixed oil. The liquid did not contain phosphoric, but *phosphoglyceric acid*.

Viscous matter decomposed by boiling with dilute acids; products.

By digestion with caustic potash the viscous matter could not be transformed into salts of oleic, margaric, and phosphyglyceric acids (the viscous matter from yelks was entirely split up), but by boiling with potash in alcohol these three acids were obtained from the brain matter.

Bearing with acetic acid.

The viscous matter from yelks and brains was soluble in crystallisable acetic acid. It could be boiled with this acid for six hours without showing signs of decomposition. Only after 12 hours' boiling a greasy matter floated on the top, which contained oleic and margaric acid, but contained yet much phosphorus.

It was necessary to boil at least 24 hours to effect a perfect decomposition. The liquid then contained glycerophosphoric acid, but also phosphoric acid and glycerine.

Tartaric and lactic acid acted in the same manner as acetic acid.

Change of opinion: viscous matter a neutral substance.

In this memoir Gobley withdrew his first view of the viscous matter being a mixture of ammonia soaps of the three acids obtained; he removed the soluble salts by washing the boiled yelks with water, extracted and chemolysed by sulphuric acid the viscous matter, and searched for ammonia in his ultimate residues. But the quantity of this base found was so small that it could not be brought into relation to the acids found, and Gobley consequently modified his opinion of the viscous matter in this direction, that it was a neutral matter in which the three acids did not pre-exist, and in fact a complex body from which he had separated two matters, one of which he named *phosphorised matter*, and the other *cerebric matter*. The phosphorized matter he now declared to be identical with Frémy's *oleophosphoric acid*, and the cerebric matter, which he now also isolated from yelks with Frémy's *cerebric acid*. But he combated the theory which this latter chemist had given of oleophosphoric acid, and maintained that the phosphorized matter contained the elements of oleic, margaric, and glycerophosphoric acids, and always split up into those acids, and never into oleine and phosphoric acid, as had been maintained by Frémy. According to Gobley, the fatty matters extracted from brains contain neither potash nor soda, but only phosphate of lime. In this memoir Gobley also replies to objections which had been made to his views of the viscous matter by Sacc (Compt. rend. 22, 649), to the effect that the phosphorus was contained in yelk as phosphorus (hypothesis of John), and only transformed into acid by the drying of the yelk in presence of air.

Opposes Frémy's views of oleophosphoric acid.

Frémy's observations on Gobley's research.

On this memoir of Gobley, Frémy made some characteristic observations (Journ. d. Pharm. et de Chim., 12 (1847) 13,) by way of reclamation for himself. He says that the researches of Gobley taught (1) that the fatty matters of yelk contain brain fat; (2) that in the decomposition of oleophosphoric acid, the glycerophosphoric acid of Pelouze may be formed. He is happy to point out that his (Frémy's) work on the brain has enabled Gobley neatly to characterise the fatty phosphorised substances contained in yelk. These claims were subsequently refuted by Gobley, and with complete justice and success. But following, as they did, as a kind of editorial rider to his publication, they for a time extinguished all sense of appreciation of the new researches in the French scientific public, and nearly prepared for Gobley the same unjust fate as that under the sting of which Couerbe had gone to his grave.

Gobley's researches on the eggs of carps.

In a later memorial, entitled "Chemical Researches on the Eggs of Carps," to which the Academy of Medicine before whom it had been read, gave its approbation (Bul. de l'Acad. de Méd. 15,471; the first two memoirs above sketched had been communicated to the Academy of Sciences), and which was published in the Journ. de Pharm., et de Chim. 17 (1850) 401; and 18 (1850) 107, Gobley stated that he had extracted from these eggs the albuminous matter, to which he gave the name of paravitelline, oleine, and margarine, though in much smaller proportions than from hen's eggs and cholesterine, lecithine, and cerebrine, besides salts, meat extract, and a peculiar acid, an odoriferous and a colouring matter. The eggs were boiled with water and pressed, and then extracted with boiling ether; the ether was evaporated and the residue boiled with alcohol; this on cooling deposited the viscous matter, consisting of cerebrine and lecithine, and in the alcoholic solution floated the crystals of cholesterine. The words *cerebrine* and *lecithine* were pointedly selected to emphasise the difference of these bodies from those described by Frémy as cerebric and oleophosphoric acids. Of all four conceptions lecithine (from eggs) alone has survived the progress of science, and complemented with choline (by Strecker) has become one of the best known bodies of the animal economy.

Lecithine from eggs.

The greater bulk of the deposited viscous matter consisted of lecithine. It was soft, formed an emulsion with water, was little soluble in cold, easily soluble in hot alcohol, and deposited from it on cooling; entirely soluble in ether; not altered by air. Heated it did not fuse, but swelled up, and on combustion left a charcoal soaked with phosphoric acid. Under the influence

of mineral acids and alkalies it always yielded with the greatest facility oleic, margaric, and phospho-glyceric acid. App No. 5.

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Gobley next combats the idea of Frémy, that lecithine was a body analogous to his sulpholeic acid, and in fact identical with the oleophosphoric acid spoken of in his brain research. Gobley never obtained oleine and phosphoric acid, but always, oleic, margaric, and glycerophosphoric acid. Thus he says he would be compelled to believe lecithine to be a mixture of oleo-phosphoric and margaro-phosphoric acid. When neutral oleine and margarine are present they are not essential results of the reaction, but admixtures, which were present before the decomposition of lecithine commenced. But how can Frémy explain that he never found margaric acid, which Gobley never missed? Gobley recognized that the peculiar white matter which Vauquelin, Couerbe, and Frémy had extracted from the brain was also present in the viscous matter from eggs of hens and carps. In order to obtain it he decomposed the viscous matter (200 grms.) with alcohol of 88° strength (500 grms.), and 50 grammes of sulphuric or hydrochloric acid. After several hours' standing the mixture was slowly heated to boiling, and then allowed to cool. It deposited white *cerebrin*, with some cholesterine. After filtration the latter was removed by ether. Re-solution in hot alcohol and treatment with ether purified the substance. It is neutral, fuses between 155 and 160°, and becomes black at the same time. In water it swells like starch; it contains no sulphur. It easily retains small quantities of other bases or acids which have been in contact with it, but without combining with them in atomic proportions.

Decomposition products.

Cerebrine from eggs.

By elementary analysis it yielded:

	In 100.	Frémy's cerebric acid.	R. D. Thompson.
C	66·85	66·7	67·04
H	10·82	10·6	10·85
N	2·29	2·3	2·24
P	0·43	0·9	0·46
O	19·61	19·5	19·41

In short the identity of cerebrin from eggs (though it was changed by influence of acid, as shown by fusing point T.) with that from brain seemed proved by this research, although the identity of lecithine from eggs with any of the phosphorised bodies from brain was not yet certainly established.

In the Journ. d. Pharm. et d. Chim. 19 (1851), 406, Gobley published a memoir on the chemical ingredients of the milt of carps, in which he showed that it contained the same ingredients as the eggs. He points out that it presented great analogy in properties and composition with the brain. In vol. 21 (1852), 241, he further describes the fatty matters of the venous blood of man, after having summarised previous researches; he finds oleine, margarine, cholesterine, but maintains the absence of all soaps, or free fatty acids. He further finds lecithine and cerebrine as previously defined by him. The séroline of F. Boudet he considers as a mixture of oleine, margarine, cholesterine, and a little albumen. The blood of the ox yielded the same results as the blood of man. The last memoir of this author, which concerns us in this place, treats of the fatty matters contained in the bile (Journ. d. Pharm. et d. Chim. 30 (1856), 241). He maintains that the fatty acids obtained in the chemolysis or putrefaction of bile are products of the splitting up of lecithine naturally combined in it, but that, although fatty acids are not present in the bile, neutral fats and cholesterine are normally present.

Gobley on the milt of carps.

The same on the fats in the venous blood of man.

Opinion on Boudet's séroline.

The same on the fats in bile.

At this point Gobley relinquished the research; he could not obtain his lecithine in a state of purity, and the methods at his command were evidently exhausted on every field. It was not till Strecker resumed the investigation of lecithine in bile that any progress was made in the recognition of that substance. For Müller, who published his paper in the following year, appears to have completely ignored Gobley's many and laborious researches, and, in some particulars, brilliant discoveries.

Müller published the first part of his researches in Ann. Chem. 103 (1857) 131, of which the following is an abstract: W. Müller.

Liebig, in his essay on the extract of flesh, had raised the question whether the brain furnished products similar to those of the muscular tissue, or yielded

Liebig's preliminary experiment.

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Two baryta salts obtained, but no kreatine.

Bibra's process.

matters peculiar to itself. He pounded the brain substance into a thin milk with baryta water, passed it through a fine hair sieve, and boiled. A coagulum was obtained containing the brain fat, and a clear yellowish liquid, which, after it had been freed from excess of baryta by carbonic acid and heat, contained two baryta salts, one soluble in alcohol, both soluble in water, and giving with acids white flocculent precipitates. Having convinced himself that the extract did not contain any kreatine, he did not carry on the inquiry any farther. It was taken up by Von Bibra, who varied the process a little, by extracting the comminuted brain with cold water, allowing the mixture to stand for 12 hours, decanting the supernatant liquor and coagulating by heat. The clear acid filtrate was treated with baryta water and gently heated, whereby the greater portion of the albuminates was precipitated. The concentrated fluid on standing deposited no crystals, from which Bibra inferred the absence of kreatine; he was not more successful in his endeavour to find inosinic acid, inosite, and hypoxanthine. But he found volatile organic acids, among them formic, identified by the silver reduction test, and fixed organic acids of which he identified lactic.

Fails to find kreatine.

Found formic and lactic acid.

Hot alcoholic solution of deposit on cooling of alcoholic extract of brain.

Cerebrate of potassium.

Analysis of cerebric acid.

Von Bibra treated the hot alcoholic solution of the substance deposited on the cooling of the alcoholic extract with potash, and boiled. On adding sufficient alcohol, the fluid became of a darker colour, and perfectly clear after some hours. After cooling, and standing 24 hours, nearly all the cerebric acid is deposited as cerebrate of potassium. This is purified by decomposition with hydrochloric acid, &c., until finally pure cerebric acid is obtained. This is a white powder, which is not in the least coloured yellow, it is lighter than water, but swells up in it like starch. It melts at a temperature almost identical with that which effects its decomposition. Bibra gave as the results of his analyses:

C	66·93	66·66
H	10·73	10·58
N	2·48	2·54
P	0·52	0·52
O	19·34	19·70
	100·00	100·00

Acid nature doubtful.

Reactions.

Bibra could not obtain a combination of cerebric acid with either potassium, baryta, copper, or silver, which renders the acid character of this body doubtful. He says that with sulphuric acid in the cold, cerebric acid quickly assumes a purple tint, and after some time becomes black. On treating with an excess of warm dilute sulphuric acid, a black magma is obtained, which, when diluted with water and filtered, leaves on the filter a darkish brown, sticky body, which dries up into a glistening resinous body. With fresh bile, water, and sulphuric acid it assumes a red colour like sugar. With concentrated cold nitric acid after some time, cerebric acid assumes a yellowish tint, and with concentrated hydrochloric acid a feeble violet or reddish tint. Boiled with nitric acid, nitrous acid is evolved, and a clear yellow fluid is finally obtained.

Not easily attacked by strong acids.

If cerebric is boiled with hydrochloric acid, and the boiling be interrupted before everything is dissolved, then on washing the residue with alcohol, and dissolving in boiling alcohol or ether, unchanged cerebric acid (under the microscope) will be found. So that cerebric acid withstands the action of the strong mineral acids pretty long, and is not so easily decomposed as cholesterine.

Müller attempted, in the first instance, to repeat and enlarge the experience of Liebig and Bibra.

Müller investigates Liebig's two acids.

Method of obtaining a clear filtrate.

Human brain was worked up with baryta water to a thin milk, and after 12–18 hours worked through a sieve and boiled, the coagulum was filtered off. The filtrate was yellow, more or less opalescent, and ran through the filter quickly at first, but gradually the filtration proceeded more slowly, and a considerable portion of the fluid remained with the coagulum. A little sulphate of lime solution was added to the fluid before heating as recommended by Liebig, but a clear filtrate could not always be obtained. It was found that by allowing the fluid to boil up strongly many times in succession the

coagulum separated in large flakes, whilst the filtrate quickly ran through clear. The yellowish strongly alkaline fluid thus obtained was saturated with carbonic acid. There appeared to be a combination formed between an albumenoid substance and part of the baryta which carbonic acid was unable to split up, as the fluid remained alkaline after passing a strong current of carbonic acid for some hours and subsequent heating.

Filtrate could not be made neutral with carbonic acid.

This filtrate containing Liebig's two baryta salts was evaporated at a gentle heat. Yellowish skins formed on the surface of the fluid during evaporation, and on the sides of the dish a thin yellowish granular matter was deposited, which increased as the liquid became more concentrated. This deposit was filtered off and dried, when it assumed a yellow hornlike appearance, burnt with a nitrogenous smell, and left an ash of carbonate of barium. Its reactions proved it to be an albuminous body.

Filtrate evaporated.
Skins formed.
Deposit is albuminous.

The fluid filtered from this albuminous deposit was evaporated on the water bath until there remained a yellow syrup containing grey membranous flakes. This syrup was now treated with strong alcohol, which threw down a membranous flocculent white precipitate. This precipitate was exhausted with 84 % spirit. The alcoholic extract should contain the baryta salt soluble in alcohol, and the residue should contain the salt soluble in water. Cold and boiling water, however, extracted but very little substance which was obtained on evaporating the aqueous extract as a yellow mass, burning with a nitrogenous smell and leaving but little ash. It redissolved easily in water, and this solution contained albumen, as shown by the nitric acid and acetic acid, and potassium ferrocyanide tests. The residue insoluble in water proved by the violet colour, which it gave with sulphuric and boiling hydrochloric acid, to belong to the group of albuminous substances.

Filtrate evaporated.
Syrup treated with alcohol.
Residue extracted with water.
Extract contained an albuminous body.
Residue insoluble in water was also albuminous.

The alcoholic solution was yellow, clear, and strongly alkaline. It gave with strong acids and metallic salts white flocculent precipitates, insoluble in excess.

Alcoholic solution was alkaline, precipitated by acids.

By slow evaporation many fine glistening plates were obtained, which by the microscope were shown to be cholesterin. Filtered from these crystals and evaporated a small quantity of a brown smeary fat separated. This was filtered off, and the filtrate after 24 hours standing deposited many square crystals, consisting of sodium chloride and kreatin. The mother liquor contained volatile acids, proved by distillation with sulphuric acid. Other substances could not be distinguished owing to the small quantities in which they were present.

Gave cholesterin, smeary fat, sodium chloride, and kreatin.
Volatile acids.
Other substances.

The above experiment was made with human brains; 25 lbs. of ox brains treated in a similar way gave no better results, and moreover contained no creatin, but furnished a small quantity of a body which from its crystalline form under the microscope seemed to be leucin. The presence of this body appeared to keep the albuminous bodies and fats in a smear so complex that the whole of the material wasted away whilst the author was endeavouring to separate its constituents. It seems from the above that the two acids of Liebig are not constant constituents of the brain.

No creatin from ox brain, but probably leucin.

Liebig's two acids not found.

The author now determined to search for kreatin in larger quantities of brain matter, and at the same time examine all the constituents soluble in water. He employed the method used by Städeler and Frerichs (Verh. der Zürcher Nat. Gesell. IV. 1855), in their researches on the parenchymatous fluids of the tissues, slightly modified.

Lead process for obtaining kreatin.

The brain matter was pounded into a thin milk, with distilled water and acetate of lead solution added, until the whole separated into a clear blood red liquid, and a lower layer of brain pulp; it was then allowed to stand 12–18 hours, well mixed and strained through a fine sieve. The filtrate was boiled, when it separated into a coarse reddish clot, and a clear amber fluid, which filtered readily. If enough lead acetate was not added the separation and filtration were incomplete, but a further addition of lead acetate and heating ensured a successful result.

Brain pounded with lead acetate allowed to stand, heated and filtered.

The filtrate was evaporated to one quarter, and as acetate of lead gave no precipitate basic acetate of lead was added. The white flocculent precipitate thus produced was filtered off, the excess of lead in the filtrate removed by sulphuretted hydrogen, evaporated, the residue dissolved in dilute alcohol, freed from acetic acid by the addition of alcoholic sulphuric acid, the excess of sulphuric acid removed by the careful addition of baryta, and the filtrate

Filtrate evaporated, basic lead acetate added filtered from white precipitate.
Filtrate, SH_2.

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treated as stated hereafter. 50 lbs. of brains (principally ox) were used; with the exception of kreatin and formic acid all the under-mentioned substances belong to ox brains, whilst these two substances were obtained only from human brains.

Uric Acid.

White precipitate from basic lead acetate treated with H_2SO_4 filtered and filtrate evaporated.

The white precipitate by basic lead acetate was decomposed with sulphuric acid, filtered, and the filtrate evaporated when it became brown. On the surface, a crystalline pellicle formed, the crystals increasing on cooling, and standing for some days, when they were filtered off. They consisted of dark brown grains and plates. Under the microscope part consisted of tables of uric acid, part of dark brown round globules, not changing their form on the addition of acetic acid and warming. They burnt without blackening on platinum foil, melted with the smell of burnt horn, gave off white vapours smelling of cyanogen, and finally volatilised completely without residue. Both bodies were nearly insoluble in water, but easily soluble in potash. The murexide test showed the presence of uric acid; the violet colour, on the addition of potash, vanished rather quickly, leaving a reddish yellow spot, perhaps indicating the presence of xanthin or hypoxanthin.

Inosite.

Filtrate from uric acid crystals gives precipitate of inosite.

The filtrate from the uric acid crystals was evaporated until alcohol gave a permanent precipitate. The liquid was then treated as suggested by Städeler and Clœtta, with an equal volume of alcohol, and warmed slightly, whereby the turbidity vanished. On cooling, and standing several days, many shining cauliflower and stellate transparent crystals were deposited. These were filtered off and recrystallized from water. They consisted of shining rhombic prisms and needles, mostly in rosettes, of a distinctly sweet taste, easily soluble in water, with difficulty in cold strong alcohol, easier in boiling alcohol, separating, on cooling, from the hot alcoholic solution as fine glistening scales; blackening, when heated on platinum foil, with smell of burnt sugar, leaving no residue. It did not reduce a copper solution on boiling. Treated with nitric acid on platinum foil, and carefully evaporated, then treated with calcium chloride and ammonia, and again evaporated, a fleeting but brilliant rose-red colour was produced.

Analysis gave 20 %, or four equivalents of water of crystallisation (16·66% required)—

Notation in Equivalents.			Found.			
12 C	72	40·00	(by CuO)	39·28	(by Pb Cr O_4)	40·24
12 H	12	6·66		6·77		6·62
12 O	96	53·34		53·95		53·14
		100·00		100·00		100·00

Ten grammes of pure crystallised inosite were obtained from 50 pounds of brain matter used.

Kreatin.

Man, baryta coagulum boiled with 84% spirit on cooling deposited cholesterin and smeary fat. Na Cl.

The residual portion on the filter from *human* brain after treatment with *baryta*, was exhausted with 84% alcohol, and on cooling, a small quantity of cholesterine and a brown smeary fat were deposited. The clear filtrate was allowed to stand for several days, when many crystals formed, partly tetrahedra, partly octohedra, and partly square tables and fine needles, which were filtered off and dried. They were dissolved partially in boiling alcohol, and the solution evaporated, when many regular transparent tetrahedra were obtained, which consisted of sodium chloride, mixed with only a small quantity of organic matter.

Portion insoluble in alcohol was soluble in warm water; consisted of kreatin.

The residue, insoluble in alcohol, was easily soluble in warm water, and was obtained pure by recrystallisation. The crystals had the following properties: colourless shining transparent needles, and flat square tables, odourless, tasteless, without action on vegetable colours; moderately soluble in cold water, easily in warm water, almost insoluble in boiling alcohol. Heated on platinum foil become first opaque from loss of water of crystallisation, then blacken and burn off with smell of burnt horn, leaving no residue. They evolved no trace of ammonia on treating with lime, and were quite inactive to reagents. The solution in hydrochloric or nitric acids quickly evaporated, left fine rhombic prisms. On treating with sulphuric acid, a crystalline residue was left, which under the microscope was seen to consist of very fine four and six sided tables.

From the behaviour of these crystals, they seemed to be kreatin. The estimation of the water of crystallisation and nitrogen confirmed this view. App. No. 5. On the Chemical Constitution of the Brain, by Dr. Thudichum.

Contained 12·63 °/₀ of water (lost at 100°) and 32·10 °/₀ nitrogen (by soda-lime, and platinum).

Theory.			
Atoms.		In 100.	Found.
8 C	48	36·64	—
4 O	32	24·43	—
3 N	42	32·06	32·10
9 H	9	6·87	—
2 Aq	18	12·08	12·63

Kreatin only occurs in very small quantity in the brain, and Müller only proved its presence in human brains; whilst Liebig found 36 grammes in 100 lbs. of the flesh of a lean horse, 30 grammes in 86 lbs. of ox flesh, and 72 grammes in 100 lbs. of lean dog flesh, only half a gramme of kreatin could be obtained from eight human brains, equal to about 24 lbs.

Leucin. Ox brain, baryta, heat, coagulum extracted with alcohol, crystals apparently of leucin; no kreatin.

Lerch, of Prague, also found kreatin in the brain. No kreatin was obtained from ox brain when treated by baryta process, as in the foregoing paragraph, but the alcoholic extract on evaporation gave a crystalline deposit in small quantities, which consisted of leucin. Städeler and Frerichs (Verh. der Zürcher nat. Gesell. iv. 55, S. 14) found leucin in the brain. In the filtrate from the lead precipitate some analogous bodies were found, having the appearance of leucin in ox brain. To extract the leucin the filtrate from the basic lead acetate precipitate was freed from excess of lead by sulphuretted hydrogen, and evaporated to a syrupy consistence, taken up in alcohol, freed from acetate by alcoholic sulphuric acid, the filtrate freed from the excess of sulphuric acid by the careful addition of baryta water, and again evaporated on the water bath to a syrup. The brown residue, smelling strongly of roast meat, was treated with alcohol of 84°/₀, each addition of which produced a transitory turbidity, but after some time the whole of the residue dissolved. Absolute alcohol produced a precipitate of yellowish brown, sticky flakes, which quickly dissolved up in water to a thick brown liquid. The whole was mixed with an equal volume of absolute alcohol, and after standing 24 hours had separated into two layers, a lower blackish brown and an upper clear pale yellow layer. The latter was carefully decanted off, and carefully evaporated on a water bath to a thin syrup. After standing 8 days many yellow granular crystals had separated, and were filtered off. Under the microscope they consisted of large radiate, striped, round, shining globules, very much resembling leucin. Easily soluble in water, with difficulty in cold, but more easily in hot alcohol, separating out from the hot alcoholic solution on cooling as a light, white powder, insoluble in absolute alcohol. It was purified by repeated crystallisations from hot alcohol. Thus purified it appeared as a light powder, tasteless and inodorous, without action on vegetable colours. Heated on platinum foil it blackened and burnt off with the smell of burnt horn, leaving no residue. It sublimed in the usual manner, with the characteristic smell of leucin. It was quite indifferent to reagents. It appeared under the microscope to consist of fine needles concentrically grouped. Burnt with soda lime (and platinum) it gave 13·89°/₀ N. Leucin contains 10·68°/₀. It is not easy to account for this excess of nitrogen, as great care was taken to purify the substance before analysis. Gorup Besanez (Ann. Chem. 98, 15) obtained from the pancreatic glands of oxen a crystalline body very much like leucin, but differing in composition by $C_2 H_2$. The analysis given above would fit with the third homologue of the leucin series $C_8 H_9 N O_4$, which requires 13·58°/₀ of nitrogen. Müller could not find either leucin or any homologue of leucin in human brain. Frerichs and Städeler once detected leucin in the human brain in a case of acute atrophy of the liver, the patient being a female, and leucin abounding in the juices of the other organs. These investigators also searched for leucin in cases of typhus, but with unsatisfactory results. Müller principally investigated brains from cases of tuberculosis and pneumonia, and could never establish the presence of a trace of leucin.

Filtrate from basic acetate of lead precipitate; yielded crystals which had the properties of leucin, but not composition.

Nitrogen analysis.

Agrees with a homologue of leucin, $C_8 H_9 NO_4$.

Leucin only once found in human brain.

The author never once found leucin in human brain.

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Volatile acids of group $C^n H_{2n} O_2$.

Mother liquor from kreatin contains formic and possibly acetic acid.

From Bibra's researches it was probable that formic acid existed in the brain. The mother liquor from the kreatin, from the aqueous extract of human brain, was treated with excess of sulphuric acid, whereupon the odour of volatile acids was immediately noticed and distilled. The distillate was colourless, and strongly acid, with a powerful odour of formic or butyric acid. On adding solution of nitrate of silver, a voluminous white precipitate fell, which blackened in the cold, and on boiling was almost entirely reduced. The filtrate remained clear on cooling. On evaporating, a small quantity of fine needles separated, but not enough to determine with certainty the nature of the acid present, but from the appearance of the crystals they were supposed to consist of acetate of silver. Thus in human brain formic acid was found (and possibly acetic).

Mother liquor of leucin body from ox brain yields acetic and trace of formic acid.

The aqueous extract of ox brain, after the leucin-like body had been separated, and gave no further precipitate with either alcohol or ether, and was concentrated, treated with dilute sulphuric acid in excess, and distilled. The distillate was colourless, very acid, and smelled strongly of acetic acid; it was neutralised with carbonate of soda, and evaporated; on cooling large rhombic tables of sodium acetate crystallised out, which were separated off. The mother liquor on further concentration left a silky crystalline mass. This was distilled with dilute phosphoric acid. The strongly acid distillate having a powerful odour of acetic acid, reduced a solution of nitrate of silver but slightly. It was neutralised with baryta water and evaporated. On standing it deposited many thin prismatic needles of baryum acetate, containing 59·7% of baryum, pure acetate containing 60·03%. So a trace of formic and a quantity of acetic acid were found in the aqueous extract of ox brain, but all the acetic may have been derived from acetate of lead added.

The acetic acid may have been derived from the lead acetate added.

Lactic acid found by Bibra.

Residue after distilling off volatile acids exhausted with ether.

Ether extract gave calcium lactate.

Lactic acid had been found by Bibra both in the residue after distilling off the volatile acids, and in the fresh aqueous extract obtained according to Liebig's method. Müller's investigation was therefore limited to determining the atomic weight of the calcium salt, and thereby proving the identity. The treatment of the residue was modified, so that if succinic acid were present it might be detected. The residue was therefore first exhausted with ether as long as the ethereal extract continued yellow. The ethereal solution was allowed to evaporate slowly, but the dark yellow, strongly acid syrup which remained did not deposit any crystals, even after standing eight days. The residue was then treated with absolute alcohol, in which it dissolved to a clear yellow fluid. The solution was treated with milk of lime, boiled and filtered hot. On cooling a quantity of white crystals were deposited, partly granular and partly acicular, which under the microscope revealed the well-known tufted forms of calcium lactate. They were purified by recrystallisation from strong alcohol, when they had the following properties:

White, rather light powder, tasteless, inodorous, easily soluble in water and boiling alcohol, but difficultly soluble in cold alcohol. Heated on platinum foil blackens, leaving a residue of calcium carbonate. Gave 29·6% of water, and 18·49% calcium.

Theory.			In 100.	Found
1 equivalent of	lactic acid	81	= 52·59	—
1 „	lime	28	= 18·18	18·49
5 „	water	45	= 29·23	29·60

12 grm. from 50 lbs. of ox brain.

From 50 lbs of ox brain 12 grammes of calcium lactate were obtained.

Other substances in minute quantities.

Besides the above-mentioned bodies Müller found none present in the aqueous extract of the brain in sufficient quantity to determine their composition. Several substances however were obtained in minute quantities.

A nitrogenous body from basic acetate of lead precipitate.

A second body from same precipitate.

A brown nitrogenous body was obtained from the basic lead acetate precipitate with uric acid, crystallising in microscopic spheres. This basic lead precipitate also contained a second nitrogenous body in small quantities.

Acid mother liquid from inosite treated

The mother liquor from the inosite, after the addition of absolute alcohol produced no further crystallisation of inosite, was neutralised with baryta water; no turbidity ensued. It was then evaporated to one quarter and treated with at least an equal volume of alcohol when a white precipitate fell consisting principally of baryum chloride mixed however with a small quantity of organic matter. The filtrate from this precipitate was evaporated to a syrup

and allowed to stand, when yellowish granular and warty glistening crystals were deposited, easily soluble in water hot and cold and alcohol; blackening and burning with a luminous flame when heated on platinum foil; leaving a residue of baryum carbonate. These crystals did not consist of inosate of baryum as proved by the sulphate of copper test (a white precipitate fell but no blue color was produced). An aqueous solution of the crystals gave a voluminous white precipitate with basic acetate of lead.

deposited crystals which were not inosate of baryum.

Another nitrogenous body was obtained from the filtrate from the lead precipitate, by heating the residue in the retort, after distilling off the volatile acids and exhausting with ether, as follows: the sulphates of potassium and sodium which have crystallised out are separated off, the brown filtrate is heated with calcium hydrate boiled and filtered, the clear filtrate is concentrated on the water-bath and allowed to stand. Brown tables crystallise out soluble in water burning with smell of horn and leaving an ash of calcium carbonate.

Another nitrogenous body from residue.

Crystallises.

The mother liquor from these crystals gives with tannic acid, zinc chloride, and mercury nitrate brown floculent precipitates which however shrink so much on drying as to prevent further investigation.

Mother liquor still gives precipitates with tannic acid, zinc chloride, and mercury nitrate.

The results just sketched may be summarised thus:—

Results.

1. The brain of man in the portion soluble in water contains a small quantity of *kreatine*.
2. On the other hand kreatine is not present in ox brain, but the latter contains either *leucine or a homologue*.
3. In both human and ox brain *volatile acids* of the series $C_n H_{2n} O_2$ in very small quantities exist.
4. Both human and ox brain contain considerable quantities of *lactic acid*.
5. Ox brain contains a little *uric acid* and some quantity of *inosite*.
6. Succinic acid, glycogen, kreatinine, urea, cystine, and taurine could not be found in the brain.

In some preliminary remarks introducing his second paper, Müller refers to the difficult nature of a research on the fats, &c. of the brain, and mentions that from 30 ox brains he was only able to obtain sufficient material to establish the presence of cholesterin and cerebrin.

W. Müller's second paper. (Ann. Chem. 105, 361 (1858))

The method adopted was the following:—The coagulum obtained by treating the brain matter with solution of lead acetate and heating was first extracted with hot 80 % alcohol, then boiled with a mixture of equal parts of alcohol and ether, and filtered boiling hot; on cooling a considerable quantity of a white flocculent matter was deposited, which was collected on a filter and dried. When dry it appeared as a reddish yellow crystalline mass. This coloration, on drying, was noticed by Vauquelin. Frémy attributed it to the presence of oleophosphoric acid.

Method. Coagulum by lead acetate and heat, how treated.

The reddish yellow mass was extracted with ether, until the extract was colorless, and left no residue on evaporation. A clear yellowish-red ethereal solution was thus obtained, whilst a yellowish-white voluminous insoluble residue remained. The solution contained cholesterin and a phosphorised body, having the properties of an acid, whilst the insoluble residue contained the cerebrin.

White matter extracted with ether. Cholesterin and phosphorised acid in solution. Cerebrin remains insoluble.

The ethereal solution (of the precipitate obtained on cooling the alcohol ethereal extract of the coagulum) was freed from ether by distillation. The red pasty residue, containing numerous crystals of cholesterin, was treated with alcohol, and boiled with an excess of lead hydrate. Most of the fatty acids combined with the lead, and on filtering boiling hot remained as a greyish-white powder on the filter. The filtrate, on cooling, deposited a large quantity of white shining plates, which were collected and purified by further treatment with lead, and re-crystallisation from hot alcohol.

Residue treated with alcohol and boiled with lead hydrate yielded cholesterine.

They had then the following properties:—White pearly rhombic plates, tasteless and odourless, greasy to the touch, insoluble in water, easily soluble in ether and boiling alcohol, difficultly soluble in cold alcohol. Heated on platinum foil they blackened, swelled up, and burnt with a luminous flame without leaving any residue. The substance was quite free from nitrogen and was not precipitated from its ethereal solution by reagents.

Properties.

Analysis.

Burnt with chromate of lead and a little bichromate of potash it gave the following results :—

Theory			Found
of equivalents		per cents.	
C 28	168	83·93	83·57
H 24	24	11·91	12·06
O	8	4·16	4·37
		100·00	100·00

This theory of cholesterin is, however, incorrect, its actual composition being (atomic notation) $C_{26} H_{44} O$.

Cholesterin forms one-third of the constituents of the brain soluble in alcohol or ether.

Cerebrin.

Müller prepares cerebrin as follows :—

Coagulum extracted with boiling alcohol.

Exhausted with ether. Recrystallised from boiling alcohol. Cerebrin deposited on cooling. Same result with lead coagulum.

Human brains were worked up into a thin milk with baryta water and coagulated by heating. According to Frémy baryum cerebrate is insoluble in boiling alcohol, but to Müller's astonishment on extracting the coagulum with boiling alcohol he obtained on cooling the alcoholic extract a voluminous white flocculent precipitate, which on exhaustion with ether left a yellow residue presenting after repeated crystallisations from boiling alcohol all the characteristics of pure cerebrin. In a similar way the coagulum obtained by heating the acetate of lead extract of the brain was extracted with boiling alcohol, the deposit on cooling was purified by treating with ether and taken up in boiling alcohol, when it left only a small portion of resinous matter insoluble; on cooling a white powder was deposited which was dried and crystallised from boiling alcohol until the latter left no trace of the resinous body undissolved.

Properties.

The substance purified as above had the following properties :—White loose very light powder, tasteless and inodorous, soluble in boiling alcohol and ether, the solution having no reaction on vegetable colors, insoluble in water, cold alcohol, and ether. Microscopic spheres: heated on platinum-foil cerebrin gives off the smell of burnt horn becoming brown, melting, and finally burns with a red flame, leaving a black fused charcoal burning off without residue. It blackens mercurous nitrate paper when heated with soda lime. It is insoluble in ammonia, hot and cold, in potash and in baryta water. It is unchanged by cold water, swells up like starch in boiling water changing to a thin slightly turbid emulsion which remains on cooling, and is not changed by the addition of acids, alkalies, or metallic salts. If it be evaporated a residue remains soluble in hot alcohol, from which solution cerebrin is deposited on cooling unchanged.

Reactions with HCl.

HNO^3.

H^2SO^4.

No S or P.

Decomposed at 80°.

Hydrochloric, phosphoric, and nitric acids produce no change in the cold. By boiling with hydrochloric acid the body becomes first reddish violet then it decomposes forming a brown fluid and a brown resinous body insoluble in acids and alkalies. On boiling cerebrin with nitric acid nitrous fumes are evolved, the fluid becomes yellow, and yellow oily drops form on the upper part of the flask, solidifying on cooling to a white fatty body. Concentrated sulphuric acid dissolves cerebrin in the cold with a dark purple red color; on diluting with water the colour vanishes and a yellowish white precipitate falls. Cerebrin is free from sulphur and phosphorus. It could not be dried at 100° C. as it decomposed at 80° becoming brownish yellow.

Analysis of cerebrin.

Analysis of the cerebrin dried at 75° C., when it lost no water, gave the following results :—

Combustions with chromate of lead and nitrogen estimated as ammonio-platinum chloride—

Theory.				Found		
C	34	204	68·23	68·35	68·56	—
H	33	33	11·04	11·30	11·25	11·06
N	1	14	4·68	4·69	4·53	4·29
O	6	48	16·05	15·66	15·66	—

Cerebrin not cerebric acid minus the phosphorus.

Müller points out that these figures prove that his cerebrin is not identical with Frémy's cerebric acid, minus the phosphorus, because the above percentages

of carbon and hydrogen are higher than those obtained by Frémy, so that Frémy's cerebric acid was probably contaminated with some phosphorised fat.

Discussion as to the acid nature of cerebric acid.

Is not an acid, but a neutral nitrogenous body.

Müller then proceeds to discuss the supposed acid nature of Frémy's body. The solubility of the supposed insoluble baryum and lead cerebrate in alcohol has already been mentioned. He treated boiling alcoholic solution of cerebric acid with sufficient potash solution and obtained a voluminous white precipitate which on further boiling partially redissolved. Filtered boiling hot nearly pure cerebrin remained on the filter. Treatment with baryta gave precisely similar results; on long boiling a yellow resinous insoluble body was obtained sticking to the sides, probably from a primary decomposition of cerebrin and combination of the products of decomposition with the alkalies. Moreover, as Frémy dealt with an impure substance, and states that it combined with the baryta, it becomes a question how far the impurity and how far the cerebric acid took part in the combination. At all events the reasons adduced by Frémy will not suffice to prove this body to be a well characterised acid; on the contrary, its behaviour towards vegetable colours and bases proves that it belongs to the class of neutral nitrogenous bodies, and if it could be combined with bases it might be said that other neutral bodies as glycin, allantoin, &c., do the same.

Names it *cerebrin*.

Gobley's cerebrin.

The author therefore assumes the name "cerebrin" for his new substance; the cerebrin discovered in the blood fats by Gobley was probably a combination of cerebrin with a phosphorised fat.

Reactions with nitric acid.

Some cerebrin was placed in a retort with concentrated nitric acid, a receiver was attached and the retort gently heated; at first the substance somewhat swelled up, soon vapours of nitrous acid were disengaged, and a clear liquid went over into the receiver. The red fumes increased with much frothing, whilst the substance became transparent. As soon as it began to boil the substance changed suddenly into a yellow transparent oil, which floated on the yellow nitric acid, and for some long time underwent no further change. The distillation was now stopped, and the contents of the retort poured whilst hot into a beaker, the yellow oil solidified into a yellowish white solid fatty body, which was freed from nitric acid by filtration and washing; it was then dissolved in boiling alcohol and filtered boiling hot, when after 24 hours' standing a white granular fatty body separated; this fatty body was purified by recrystallisation, and obtained as a white waxy mass, soluble in alcohol and ether with moderate facility; in alcoholic solution it had a slight acid reaction.

Oily body formed.

Properties.

Under the microscope it was seen to consist of minute fat globules, without a trace of crystals. Heated on platinum foil it melted quickly to a yellowish fluid, blackened and burnt with a ruddy flame, evolving pungent odours of burnt fat.

Analysis.

On analysis it contained 12·92 °/₀ hydrogen, 75·52 °/₀ carbon, and probably no nitrogen.

	°/₀ found.	÷ by At. Wgts.	÷ O as 1.
C	75·52	6·293	8·71
H	12·92	12·920	17·89
O	11·56	0·722	1·00

$= C_9\ H_{18}\ O$, or $C_{17}\ H_{36}\ O_2$ (atomic notation).

Brain Fats.

Alcoholic mother liquor from cholesterin or cerebrin boiled with lead hydrate.

Precipitate treated with ether.

The alcoholic solution of the coagulum after the cholesterin and cerebrin had been separated was treated with hydrate of lead and boiled. A lead salt of a fatty acid, mixed with the excess of hydrate of lead went down. The precipitate was filtered off and exhausted with ether. A bright reddish-yellow ethereal extract was thus obtained, whilst the lead salt remained as a fine powder.

Ethereal extract evaporated.

Residue partly soluble in boiling alcohol.

Insoluble residue dissolved in ether.

Evaporated.

Left 20 grm. of reddish yellow body.

The extract on evaporation left a reddish yellow waxy mass, a small portion of which was soluble in boiling alcohol, and was obtained as a fine white powdery lead salt, decomposing and turning brown at 70°. The residue insoluble in boiling alcohol was redissolved in ether, a small quantity of a yellowish-white powder remaining undissolved; the solution was filtered, and the dark red alkaline filtrate evaporated spontaneously, leaving a considerable quantity of a hard fixed reddish brown body, which on powdering became of a reddish-yellow colour. About 20 grammes were obtained. It was not changed by further solution in ether and evaporation. Insoluble in water and alcohol,

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soluble in ether. Heated on platinum foil it blackened, melted, swelled up, gave off a peculiar smell, and burnt with a red flame, leaving behind a considerable residue of metallic lead, oxyde of lead, and pyrophosphate of lead. It contained no nitrogen and no sulphur. On analysis it was found to consist of a mixture of lead salts. The lead was estimated by fusion with nitre, dissolving the residue in nitric acid, and precipitating by sulphuric acid. It contained—

Properties.
No N or S.
Mixture of various bodies.
Analysis.

44·86	45·17 and 42·86 % lead.
29·7	29·19 and 28·26 % carbon.
4·31	4·19 hydrogen, and 3·72 % phosphorus.

Baryta salt of above prepared.

These differences are too great to be accounted for by defects in the analysis, moreover the baryta salt does not agree with the lead salt. The baryta salt was prepared by treating the lead salt with sulphuretted hydrogen suspended in water. The filtrate from the lead sulphide was yellow acid and clear. It was evaporated on the water bath to drive off the sulphuretted hydrogen, and the fluid divided into two parts, one was further evaporated on the water bath and allowed to stand. After many days standing a solid soft reddish brown sticky acid mass separated, which only partially redissolved in alcohol. The other portion was treated with baryta water, which produced a yellow flocculent precipitate, it was filtered off and dried when it became reddish-yellow, and easy to powder. Heated on platinum foil it left an ash of carbonate and phosphate of baryta. The body was insoluble in water, alcohol, and ether, and contained 32·81 % baryum.

Body not glycerophosphate or oleophosphate.

It could not be glycerophosphate, as the glycerophosphate of bargum is easily soluble in water; nor could it be oleophosphate, since the free body was soluble in alcohol, whereas oleophosphoric is only soluble in ether.

Müller thinks it safest to consider the question as to what form the phosphorus is contained in the brain fats as unsettled.

Portion of lead salts insoluble in ether.

The residue of the lead salts of the fatty acids insoluble in ether was a dirty yellow light powder, insoluble in water, alcohol, and ether. It was treated with sulphuretted hydrogen whilst suspended in water; the filtrate evaporated considerably on the water bath, and then allowed to evaporate spontaneously. After several days the residue had separated into a yellow, oily, acid layer, and many pearly-white scales; the latter were filtered off, and obtained white by recrystallisation from alcohol. Easily soluble in alcohol and ether, left no residue on ignition. The quantity was too small to purify or investigate further.

White scales.
Properties.

Conclusions.

The conclusions thus arrived at may be stated:—

1. The brain contains a very considerable quantity of cholesterin.
2. Also a considerable quantity of a nitrogenous body with the formula $C_{34} H_{33} NO_6$.
3. Also a body containing phosphorus which forms with lead a compound soluble in ether.
4. Also volatile and fixed fatty acids.

Liebreich's *Protagon*.
Brain washed *in situ*.

O. Liebreich's research on protagon was published in Ann. Chem. 134, 29.

When an animal is killed by severing the carotid arteries, and water injected into the arteries and through the brain until it leaves the veins colourless, the entire brain or the greater part of it is obtained free from blood. It may be removed from the cranial cavity and liberated from its membranes with facility, as these latter have become dropsical. The brain substance is then cut to pieces or kneaded with the hand and triturated in a mortar, and then mixed with water and ether in a bottle and shaken. The mixture is then allowed to stand at 0° C. until the ether has collected on the surface. The ether is then removed and contains besides cholesterine a very little protagon. This extraction is repeated, and has for its result that the greater part of the cholesterine is removed from the brain matter, whilst the ingredients which are easily soluble in water pass into the water.

Comminution of brain matter.
Cholesterin extracted by ether.
Treatment with alcohol.

Alcohol solution at 45° deposits flakes on cooling.
Flakes washed with ether, dried, and recrystallised.

The brain matter is now freed from water and ether by filtration digested with spirit of 85 % strength, in a water bath at 45° C., and the alcoholic solution filtered off on a hot funnel kept also at 45° C. This extract is then cooled to 0° C., when it deposits a copious flaky precipitate. This precipitate is collected on a filter and washed with cold ether until no cholesterine is extracted

by the ether. It is then dried in vacuo over sulphuric acid, afterwards moistened with a little water and dissolved in spirit at the temperature of 45° C. This saturated solution is again filtered at 45°, and then allowed to cool gradually in a large water bath to the temperature of 16° C. Minute crystals are deposited, visible as crystals only under the microscope. If the solution had the proper degree of concentration these crystals assumed the form of needles in radiary arrangement. In very concentrated solutions the crystals are bent and distorted. They can be recrystallised until pure.

Crystals obtained by gradual cooling.

Purified by recrystallisation.

Another method of obtaining protagon is the following. The brain is triturated with water and ether, and allowed to stand for some time at the ordinary temperature. The ether absorbs fatty acids produced by the decomposition of a portion of the protagon and much protagon which is easily soluble in the products of its decomposition. The mixture is heated to 29° C., the ether separated off, filtered, and cooled down to a very low temperature. The protagon separates as a white precipitate, which is placed on a filter, washed with cold ether to remove cholesterine, dried, and recrystallised from alcohol as described above.

Brain extracted with water and ether.

Ether extract cooled to 0° C.

Protagon deposited.

Protagon thus prepared gave following analyses and theory leading to formula $C_{116}\ H_{24}\ N_4\ O_{22}\ P$.

Mean of analyses.

Theory. Atoms.	%	Mean found
C_{116}	67·21	66·74
H_{241}	11·59	11·74
N_4	2·7	2·8
P_1	1·5	1·23
O_{22}	17·0	17·49
	100·00	100·00

The carbon was usually a little low and hydrogen high. The phosphorus varied from 1·1 in ox to 1·5 in human brain.

(The hydrogen, to make an even number with the nitrogen, must be either 240 or 242).

Protagon recrystallised from alcohol and dried in vacuo over sulphuric acid is a light flocculent powder. The crystals obtained from dilute alcohol assume a wax-like appearance before they part with all their water.

Peculiarities of protagon.

In cold alcohol and cold ether the substance is but little soluble, more soluble in proportion as these solvents are warm. In absolute alcohol, protagon cannot be heated above 55° C. without decomposing; a solution which has been thus treated, exhibits oily drops, and on cooling, deposits round balls, besides crystals, denoting that a decomposition has taken place. Treated with water, protagon swells, and becomes an opaque mass, resembling flour paste. By dilution with more water, a clear but opalescent solution is obtained. When the watery solution is mixed with concentrated solutions of salts, such as calcium chloride, sodium chloride, &c., a coagulation ensues. The flakes of protagon which float about the fluid may be filtered off; the filtrate seems to be free from protagon. The precipitate is not a chemical compound, for on the filter the salts can be washed away, and during washing the protagon swells up again. But it is difficult to obtain it quite pure without great loss, as the purer it becomes, the easier does it pass through the filter. In glacial acetic acid protagon dissolves, giving a clear solution, which on slow cooling, furnishes crystals similar to those obtained from alcohol. Protagon decomposes when submitted to a temperature below 100° C. The dryer the substance is, the more quickly does it decompose. At a temperature 75°–80° C., the flaky matter becomes soft, and may be kneaded together. Protagon which has been boiled, and thus swollen with water, may be dried in vacuo over sulphuric acid, and on solution in alcohol, the whole of the original matter crystallises out on cooling, unchanged. When heated more strongly, protagon fuses, becomes brown, burns with a yellow sooty flame, and leaves a black dense charcoal, which has an acid reaction when moistened with water, from the presence of phosphoric acid. This latter substance also prevents the ready combustion of the carbonate.

Solubility in ether and alcohol.

Behaviour with water and saline solutions.

Soluble in glacial acetic acid.

Influence of heat.

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Decompositions of protagon. Decomposition with baryta water. Glycerophosphate and neurine formed and separated. Calcium glycerophosphate. Baryum glycerophosphate.

Protagon is boiled with concentrated baryta water for 24 hours. The excess of baryta is then precipitated by carbonic acid; the precipitate filtered off. The filtrate contains glycerophosphoric acid combined with baryum and a new base neurine. The baryta salts of several fatty acids remain with the baryum carbonate. The entire filtrate is concentrated on the water bath at a moderate temperature, and precipitated with basic lead acetate. This precipitate contains the glycerophosphoric acid; the filtrate from it contains the neurine. The lead precipitate is suspended in water, and decomposed with hydrothion yielding a strongly acid fluid. This is filtered from the lead sulphide, saturated with calcium carbonate, and concentrated; it deposits while hot the characteristic scales of calcium glycerophosphate.

The baryum salt may be obtained by concentrating the watery filtrate from the protagon after treatment with excess of baryta water, at a moderate temperature, and ultimately in vacuo over sulphuric acid, removing any carbonate or phosphate of baryum which may be precipitated. A transparent glass-like mass is thus obtained, which is very hygroscopic. It is extracted with absolute alcohol as long as anything (neurine) is extracted. The baryum glycerophosphate remains as a white powder, easily soluble in water. In the *aqueous* solutions of baryum or calcium glycerophosphate the presence of phosphoric acid cannot be proved by the ordinary tests for that acid; it can only be shown after calcining the salts. When the salts are treated with acid sodium sulphate the characteristic odour of acrolein is evolved.

Reactions of glycerophosphate.

Fatty acid obtained from protagon.

The baryum salts of the fatty acids remain with the baryum carbonate in the residue, from which the solution of glycerophosphate and neurine has been filtered. The following steps may be taken to effect their separation :—

The entire residue is treated with dilute sulphuric acid, and then agitated in a bottle with ether. The ether containing the fatty acids is evaporated; the residue dissolved in alcohol and precipitated with an alcoholic solution of lead acetate. The dried lead soaps are repeatedly treated with ether; there remains a lead soap insoluble in ether, which is dissolved in alcohol and treated with sodium carbonate to obtain the soda soap. This, dissolved in alcohol, is precipitated fractionally by baryum chloride. The second and third precipitates contain 19·08 and 18·7 % of Ba. The acid contained in the first salt after separation fused at 57·5° C.: that of the second salt fused at 52·5° C.

Stearic acid.

New acid.

The fatty acid seems to be impure stearic acid. The impurity seems to be an acid the lead soap of which is soluble in ether. It does not seem to be either palmitic or oleic acid, but a new hitherto unknown acid. When it is obtained in the free state after the manner prescribed by Gottlieb for oleic acid, it appears as a white gelatinous vibrating mass, which can be obtained crystallised in little needles from its alcoholic and ethereal solution. It contains neither nitrogen nor phosphorus. At higher temperatures it decomposes, yielding fluid acids.

Decomposition of protagon by hydrochloric acid.

When protagon is boiled for 12 hours in very dilute hydrochloric acid in the dark, white flakes and a yellowish fluid result. If these flakes be placed on a filter and washed until the water passes through opalescent, they resemble much the swollen protagon, but are much more transparent. Dissolved in alcohol and crystallised slowly, this matter deposits needles very similar to those of protagon. The alcoholic solution, when exposed to the rays of the sun, is decomposed, depositing a reddish brown powder, and assuming a reddish colour. The crystals contain no phosphorus. When more concentrated, hydrochloric acid is employed, a decomposition ensues which results in the production of smeary matters.

H. Koehler.

Koehler's research was published in the form of a dissertation, entitled:

De Myelini quod vocant constitutione chemica disqu. Halae 1867. (German version in Virchow's Archiv. Also more full and last publication: Chem. Unters. über die fälschlich Hirnfette genannten Substanzen und ihre Zersetzungs-producte. Halle, 1868.)

First alcohol watery extract.

The author hardened the brain as much as possible in alcohol at 35 to 45°, and thereby obtained a *first alcoholic watery extract*. From this he obtained, by various operations, formic acid; a volatile fatty acid containing more than 8 C and H atoms; lactic acid, inosite, hypoxanthine, kreatine (if the brain was human), albumen; cholesterine, but no glycerophosphoric or stearic acid, and no

Lead precipitate.

neurine. Several of these matters were obtained by the agency of lead acetate

added to the solution, which produced a copious precipitate. Two cows' brains gave 248 grains of this Pb precipitate. The precipitate was insoluble in water, ether, and alcohol, and could be boiled with these agents without apparent change. It was suspended in water, and treated with hydrothion; the mixture filtered and the sulphide of lead extracted with boiling water. The extracts were evaporated to a syrup, and put in a cool place for some days. Crystals formed in the syrup, but could not be separated. Therefore, the whole was dissolved in boiling water, and mixed with four volumes of absolute alcohol. A white, powdery, yet adhesive, precipitate fell, which was recognised as hypoxanthine. The solution on standing deposited inosite.

Hypoxanthine inosite.

The solid brain matter which had thus been hardened in alcohol, and yielded to it some of its more soluble matters, was now exhausted with ether, in an apparatus surrounded with ice. The yellow, clear, transparent, ethereal extract was concentrated by distillation at 40° to one quarter, and then precipitated by absolute alcohol added gradually, until a filtered sample was not any longer made turbid by more alcohol. A white adhesive neutral substance was deposited, which the author termed *myeloidine*.

Ether extract. Precipitation by alcohol.

It will be seen that this process is the same as that of Couerbe, and that thus far myeloidine is nothing but the cephalote of Couerbe.

The myeloidine was washed with alcohol, and dissolved in water; the solution was filtered through a bag, and required constant stirring to get it through its meshes. The cholesterine contained in the myeloidine mostly remained in the bag. To the thick turbid filtrate neutral lead acetate was now added, which produced a copious precipitate. This was extracted with alcohol at 30° to 35° C, and dried over H_2SO_4. It was next digested with ether, which extracted cholesterine and *myeloidinate of lead* (to be described below), it was further extracted with boiling ether. There remained a white salt insoluble in cold and boiling alcohol, and ether, which dried at 100° in the air bath, was analysed.

Myeloidine. Purification. Lead salt. Analyses.

C	48·11	49·66	—
H	7·56	7·65	—
N	1·77	1·55	—
P	3·59	2·91	2·29
Pb	22·02	21·81	20·37
O	16·95	16·42	—

Leading to formula $C_{40}H_{76}NPPbO_{10}$.

Formula.

The free myeloidine was obtained from this lead salt by suspension in ether, and treatment with dry hydrothion until a small portion of the lead salt remained undecomposed. (The wording suggests that an excess of hydrothion might have to be avoided.) The ruby-red solution was filtered from the sulphide of lead and mixed with alcohol, when it produced a white reddish precipitate, which was dried in vacuo, but apparently not analysed.

Free myeloidine by decomposition of Pb salt by H_2S in ether.

Or the myeloidine lead was suspended in water, treated with hydrothion, and the myeloidine extracted with ether.

By hydrothion in water.

The watery solution of myeloidine gave precipitates with tannin and metallic salts.

The Alcoholo-ethereal Mother Liquor, filtered from the myeloidine, was precipitated with hot alcoholic neutral lead acetate, and yielded a copious deposit. The precipitate was filtered, washed with water, afterwards absolute alcohol, and dried in vacuo over sulphuric acid. It was a yellow, loose, easily powdered salt. On being digested with ether it dissolved, leaving a little myeloidine lead undissolved. The solution was freed from ether, partly by distillation, partly in vacuo; and this resolution in ether was repeated until the solution remained quite clear, when it was precipitated by absolute alcohol. It was found to have the empirical formula $C_{74}H_{133}Pb_3N_2PO_{23}$, as derived from the following analyses:

Mother liquor. New lead salt soluble in ether. Formula.

				Mean.
C	35·42	35·71	35·49	35·54
H	5·52	5·63	5·41	5·52
N	1·15	—	—	1·15
P	1·06	1·13	—	1·09
Pb	39·42	40·89	—	40·15
O	—	—	—	16·55

Analyses.

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The phosphorus was determined by the method of Carius. The salt, suspended in alcohol, was decomposed by hydrothion, until a minimum remained undecomposed, because, as the author says, an excess of hydrothion was hurtful. After evaporation of the filtrate from the sulphide of lead in vacuo, there remained a body free from lead, tallow-like, yellowish; fusing at 30°, fluid at 34°; soluble in ether, alcohol, and fatty oils, and having an acid reaction. This was termed *myeloidinic acid*. The theory of the free acid, after deduction of lead, is as follows:

Analysis of Myeloidinic acid.

	% in 100 of organic matter.
C	59·38
H	9·22
N	1·92
P	1·82
O	27·65
	99·99

Properties and reactions of its alcoholic solution.

The acid was insoluble in cold water, swelled at 45°; on long boiling in water it decomposed and dissolved. Its alcoholic solution was precipitated in white flakes by alcoholic ammonia; the same solution produced the original precipitate with lead acetate. Basic copper acetate produced a precipitate; tannin a yellow precipitate, insoluble at 100°. Concentrated sulphuric acid produced a turbidity; the mixture after evaporation of alcohol left an oily body. Alcoholic baryum acetate produced no precipitate in its alcoholic solution. Myeloidinic acid is decomposed by hydrochloric acid; when separated by this acid from lead salt it appears in the shape of swelled lumps.

The author leaves it doubtful whether this acid is already formed in the brain, or produced by the chemical operations from a neutral substance.

Neurolic acid is stated by Köhler to be a decomposition or metamorphic product of myeloidine. It is obtained:—

Neurolic acid.

First process.—Myeloidine lead is suspended in ether, and decomposed by hydrothion, and the mixture is evaporated. Alcohol is added, which leaves sulphide of lead behind on filtration (from this it appears that the free myeloidine is soluble in (hot?) alcohol T). The solution is again evaporated with water, and then leaves an oil and flakes. Or myeloidine lead is suspended in alcohol, treated with hydrothion, and the filtrate evaporated to a syrupy consistence on the water bath.

Second process.—The ethereal extract of the brain is evaporated, and the residue boiled during three to four hours with alcohol of 85 % strength; the extract is allowed to cool and filtered; the filtrate is precipitated by alcoholic lead acetate solution, and precipitate filtered off; the fluid (!) is now treated with hydrothion, and, after addition of some solid baryum hydrate, is evaporated to a syrupy consistence. After cooling the crystals, which consist of cholesterine and baryum acetate, are pressed between blotting paper; the syrup which creeps into the paper is dissolved in very little cold alcohol, precipitated with alcoholic solution of sublimate, and the precipitate dried in vacuo. It contains yet a little cholesterine. To remove this the precipitate is suspended in alcohol and decomposed with hydrothion; the cholesterine then crystallises out.

Properties of neurolic acid.

Neurolic acid is a viscid liquid, reddish, similar to ear-wax, and does not become solid at 12°. It is soluble in water, alcohol, ether, ethereal and fatty oils, even in the cold. The solutions have an acid reaction, and are easily filtered. When warmed with water on the water-bath it decomposes, and after evaporation of all water a residue of grey flakes remains, which become violet under the influence of sulphuric acid and iodine. Continued boiling with caustic potash or baryta water decomposes neurolic acid. Acetic and dilute mineral acids do not affect neurolic acid; by concentrated acids it is destroyed; concentrated sulphuric acid changes it into a red oily viscid mass. The alcoholic or watery solutions of neurolic acid are made turbid by addition of the acetates of ammonia, lead, copper, baryum, zinc, and of chloride of iron; they are, however, precipitated by both sublimate and tannin; the mercury

precipitate is white, the tannin precipitate yellow; both are voluminous and insoluble on boiling.

Calculated formula $C_{50}\ H_{90}\ P\ O_{17}$.

C	66–60·9
H	9·81–9·9–9·97
P	2·97

Erythrostearic acid.

Another compound obtained by Koehler is erythrostearic acid with lead $= C_{36}\ H_{70}\ N\ P_2\ Pb_5\ O_{20}$. It is soluble in ether, but is still less defined than the foregoing very doubtful products, which do not appear to me to admit of any approach to identification.

Myelomargarine obtained and purified.

Myelomargarine.—The brain substance, which had been exhausted as above with cold ether, was now boiled during two hours with alcohol; the filtrate was allowed to cool and deposit, and the precipitated white matter was completely freed from cholesterine by washing with ether. The matter was now boiled with alcohol *containing sulphuric acid* (*!*) and filtered boiling; calcium and sodium sulphates remained on the filter, and the solution on cooling and standing again deposited the white matter. This was again filtered, digested with cold ether, dried in vacuo, dissolved again in alcohol, and the alcoholic boiling solution filtered into alcohol containing ammonia. A powdery completely white ammonia salt fell, which was isolated and dried, stirred with water, decomposed by hydrochloric acid, washed with water, dried, washed with cold ether, and ultimately repeatedly crystallised from hot ether.

Characters:—Free from nitrogen and phosphorus.

Formula:—$C_{16}\ H_{36}\ O_5$ or $C_{16}\ H_{34}\ O_4,\ H_2\ O$.

Analysis.

	Required.	Found.
C	63·75	64·05–63·85
H	11·25	11·21–11·09
O	25·00	
	100·00	

Properties.

White soft powder, fatty to touch, soluble on warming in water, alcohol, ether, ethereal and fatty oils, separating from the solution on cooling. Not changed at 150°, becoming yellow above 150°, at 185° reddish without fusing. Heated on platinum, fuses to a reddish oil, burns with a lighting flame, and leaves an easily consumed charcoal.

The solutions of myelomargarine are neutral, and are precipitated only by basic acetate of lead (not by alcoholic solution of neutral acetate, which the author says is an important distinction from myeloidine, which is so precipitated): [and from the cerebrine-bodies, which are also so precipitated.—T.] its alcoholic solution is further precipitated by basic copper acetate and platinic chloride; the latter precipitate is soluble on boiling. The other precipitates are insoluble in hot water. Other mineral salts give no precipitates. Tannin also gives a precipitate which is insoluble in hot water. Concentrated mineral acids destroy myelo-margarine. Potash, ammonia, and baryta water form with it insoluble compounds. When mixed with cholesterine it yields the microscopic forms termed *myeline*.

From these data it is evident that Koehler completely failed in isolating any of the immediate principles of the brain which I have described as the cerebrines, phrenosines, and kerasines. Cerebrine contains nitrogen, fuses and blackens below 100°, and is in many other respects so different from myelomargarine that the two bodies could not have been mistaken for each other. But it is probable that Koehler decomposed the cerebrine and other bodies by boiling with sulphuric acid in alcohol, and that his substance is a metamorphic product.

Otto's cerebrine. Müller's process

The next investigation we have to notice is by Otto (Chem. Centr. Bl. 12 1022, 1867). Ox brain was rubbed with water to a thin paste, pressed through a cloth, mixed with excess of lead salt, after 12 hours' standing rubbed through a sieve and boiled. The coagulum was pressed, repeatedly treated with hot alcohol, and pressed; the alcoholic extracts, after cooling, were

decanted from the precipitate, and the latter exhausted with ether. The matter insoluble in ether was again dissolved in hot alcohol; the deposit which had formed after 24 hours was again dissolved and mixed with baryta water, the fluid was filtered hot from the plaster-like precipitate, and on cooling deposited cerebrine as a transparent mass, which was first dried over H_2SO_4, next at 50° to 70°. This cerebrine contained no ash, ***no nitrogen*** nor phosphorus, and on analysis gave—

Otto's analyses

C	67·2	67·6	67·8	67·8	Mean 67·6
H	11·1	11·3	10·9	11·1	„ 11·1
O	-	-	-	-	- 21·3
					100·0

These quantities divided by the atomic weights lead to

Calculation by Th.

C 5·63 × 3 = 16·89
H 11·10 „ „ „ 33·30
O 1·33 „ „ „ 3·99

Divided by oxygen as one,

O 1 × 4 = 4·00
C 4·23 „ „ „ 16·92

Formula.

H 8·35 „ „ „ 33·40 = to $C_{17}H_{33}O_4$.

Mueller's cerebrin, $C_{17}H_{33}NO_3$.
Koehler's myelomargarine, $C_{16}H_{36}O_5 = C_{16}H_{34}O_4 + H_2O$.

Hot water.

Hot HCl.

Heated in a sealed tube with water to 130°, it became a pasty mass. This again dried at 100°, was entirely soluble in absolute alcohol, and deposited in the original form and composition, analysis giving C 67·2, H 11·3 %. Heated during 12 hours with hydrochloric acid, it yielded a matter similar to fat, soluble in ether and alcohol, and deposited from the alcoholic solution as a gelatinous mass, which contained 71·2 % C and 12·2 % H. The mother liquor contained a body which fused at 66°, and contained 81·3 % C and 13·3 % H. The hydrochloric acid fluid, separated from the fat-like matters, was evaporated over H_2SO_4 and caustic potash, and yielded a syrup which could not be obtained colourless, showing traces of crystals; reduced alkaline copper solution, was precipitated by basic lead acetate (this precipitate became red on warming), and contained 41·7 % C and 7·32 % H. Koehler examined some cerebrine prepared by Otto, and reports it to be easily soluble in the cold in alcohol, ether, and turpentine; in fatty oils, chloroform, benzine, and glycerine soluble only on boiling; deposited on cooling from benzine and glycerine. Fuses a little above 150° and becomes yellow, after which it does not swell any more with water. Neutral reaction. With H_2SO_4 gives violet solution, and is destroyed. Dissolves in concentrated HNO_3, without red fumes. H Cl acts slowly, acetic acid not at all. Its alcoholic solution is precipitated by picrino-nitric acid, yellow; by silver nitrate in white flakes, which slowly darken. Both these precipitates are insoluble on boiling, and bake together. Basic copper acetate, bluish white; stannous chloride, white; both the latter insoluble on boiling. Palladium chloride, white flaky precipitate, soluble on boiling. No precipitates are obtained by the acetates of baryum, mercury, and zinc, or by iron salts.

Koehler tests some of Otto's preparations.

Diakonow on lecithin.

The next researches on the phosphorised matters were made by Diakonow (Centr. bl. No. 1, 1868).—Pure lecithin is a yellowish white waxy, in thin layers, silky, highly hygroscopic matter, soluble in ether and alcohol, swells in water, and when shaken with it forms a wax-like paste. Heated, it burns completely, leaving phosphoric acid. It contains—

C 64·27 %
H 11·4 %
N 1·8 %
P 3·8 %

These numbers lead to the formula $C_{44}H_{90}NPO_9$ + aq.

When heated in a solution of caustic baryta, stearate of baryum is given off in granules at the moment of ebullition, and the clear fluid contains glycero-phosphate of baryum and trimethyl-oxaethylammonium oxyde hydrate (neurine). These are the only three products of decomposition—

Glycerophosphoric Acid.	Stearic Acid.	Neurine.	Lecithine.

$$C_3\ H_9\ P\ O_6 + 2(C_{18}\ H_{36}\ O_2) + C_5\ H_{15}\ N\ O_2 - 3\ O\ H_2 = C_{44}\ H_{90}\ N\ P\ O$$

Type.

Type.—Glycerophosphoric acid is an anhydrohydrate, with four extra-radical replaceable H atoms—

$$\left.\begin{array}{l} H_2 \\ C_3\ H_5 \\ P\ O \\ H_2 \end{array}\right\} \begin{array}{l} O_2 \\ O \\ \\ O_2 \end{array}$$

The other two hydrogen atoms have remained from the phosphoric acid, and are therefore easily replaced by bases. In placing, in lieu of the first two hydrogen atoms in glycerophosphoric acid, the radical stearic acid twice, and once the radical of neurine in lieu of one hydrogen, we obtain—

$$\left.\begin{array}{c} 2\,(C_{18}\ H_{35}\ O_2) \\ C_3\ H_5 \\ P\ O \\ C_5\ H_{14}\ N\ O \\ H \end{array}\right\} \left.\begin{array}{c} O_2 \\ \\ O \\ \\ O_2 \end{array}\right\} = C_{44}\ H_{90}\ N\ P\ O_9$$

This compound must yield by caustic alkali stearate, and glycerophosphate and neurine. Lecithin, therefore, is a compound of an acid ether (the glyceride distearine), with an acid salt (acid phosphate of trimethyloxaethylammonium), forming an anhydride molecule. Its name might be Distearyl-glyceryl-phosphate of trimethyloxaethylammonium.

In a subsequent paper (Centr-bl. No. 7, 1868) Diakonow makes more explicit statements, and describes his mode of preparing the body, which was omitted in the first communication.

Diakonow on lecithine in brain.

Brain (cow) was extracted repeatedly with ether, the residual matter treated with alcohol at 40°, and the alcohol extract cooled to 0°; the precipitate which formed was filtered off, washed with a little ether and cold absolute alcohol, and again extracted with ether; a portion of the matter dissolved in ether, another remained insoluble (Protagon); this was repeatedly extracted with ether at the ordinary temperature; from all these extracts the ether was distilled off; the residue dried at 40° and dissolved in a minimum of absolute alcohol. On cooling the solution to 7° a white substance was deposited, which had the composition and properties of lecithin.

Amorphous not pulverisable, hygroscopic, swelling in water; forming an emulsion with it on shaking; leaves when burned phosphoric anhydride. Boiled with alkaline earths yields gycerophosphate and stearate, with neurine.

It yielded $P_2\ O_5$ 7·83 % – 7·89 %.
N 1·85 %.

Lecithine $C_{44}\ H_{90}\ N\ P\ O_9$ and aq. requires
$P_2\ O_5$ 8·378 %.
N 1·71 %.

Protagon is declared to be a body free from phosphorus, containing lecithine. Lecithine is easily precipitated from solutions in which other precipitates form. For this reason the cholesterin from brain, and the lactates from muscles, contain phosphorus. The crystalline precipitates, containing phosphorus, which Hermann obtained from blood corpuscles, Fischer from pus, Kühne from extract of eggs, are declared to be protagon. Köhler's myeloidin and myeloidinic acid are all but impurities mixed with lecithin. So says Diakonow.

Protagon should yield 3·428 % $P_2\ O_5$ while after exhaustion it yields 2·34 %. Re-crystallised from warm alcohol it loses still more phosphorus; a

App. No. 5.

On the Chemical Constitution of the Brain, by Dr. Thudichum.

body passes into the alcohol which, burned with nitre and soda, yields 7·4 % P_2O_5. Protagon, treated with much warm water, and extracted with ether, lost phosphorus until it yielded only 1·5 % P_2O_5.

Protagon boiled with baryta water, and the white precipitate extracted with hot alcohol, yields a great quantity of a matter which is deposited on cooling. This is neutral, swells in hot water, dissolves in hot alcohol and ether, but not in cold. On burning it leaves no ash, unless too much alcohol had been used, and boiling continued too long. Further boiling with baryta water does not change the matter. Treated with sulphuric acid, it reduces copperoxyde. The white precipitate contains a baryum soap and glycerophosphate; it is therefore clear that of the protagon only the lecithin is decomposed, while the glucoside remains unchanged. In this way it is intelligible how Liebreich could once obtain sugar. Frémy and Bibra described the body; Müller has described the body, obtained it pure, and termed it Cerebrin.

Lecithine from eggs: Strecker.

The following research, though made on eggs, bears upon our subject.

Strecker (Sitz. Ber. d. Acad. d. W. München, 1869, 2, 269), after some allusion to previous authors, described the manner in which he isolated lecithine from yelks of eggs. He treated them with a mixture of alcohol and ether, distilled the ether off, added spirit as long as oil continued to be precipitated, and then an alcoholic solution of $Pt\,Cl_4$ acidulated with $H\,Cl$. A precipitate of lecithine chloride + $Pt\,Cl_4$ ensued, soluble in ether, chloroform, sulphide of carbon, and benzole. It was purified by solution in ether, and precipitation with alcohol. Dried in vacuo over $H_2\,S\,O_4$; at 100° it blackened and lost weight to 5·1 %. Cadmium-chloride gave a similar precipitate, little soluble in alcohol or ether, or their mixture, easily soluble in alcohol and H Cl. According to Strecker the metals can be easily removed from the solutions of these compounds by hydrothion. The solution filtered from the sulphide being treated with a current of $C\,O_2$ and evaporated, leaves lecithine hydrochlorate as a waxy mass. The H Cl can be removed by silver oxyde; the excess of the latter by $H_2\,S$.

Formula of platinum salt.

By boiling baryta water, a spirituous solution of lecithine hydrochlorate is decomposed, and yields baryum salts of fatty acids, of glycerophosphoric acid, and choline hydrochlorate. The Pt salt has the formula $C_{42}\,H_{83}\,N\,P\,O_8\,Cl\;pt\,Cl_2$. Carbon and hydrogen were found generally higher; platinum and chlorine much lower than corresponds to this formula. The cadmium chloride salt did not admit of a definite formula, its cadmium varying between 13 and 15 %.

Theoretical formula of lecithine.

The formula $C_{42}\,H_{84}\,N\,P\,O_9$ Strecker derives, as follows, from the decomposition products:—

$$\underbrace{C_3\,H_9\,P\,O_6}_{\text{Glycerophosphoric acid.}} + \underbrace{C_5\,H_{15}\,N\,O_2}_{\text{Cholin.}} + \underbrace{C_{18}\,H_{34}\,O_2}_{\text{Oleic acid.}} + \underbrace{C_{16}\,H_{32}\,O_2}_{\text{Margaric acid.}} - 3\,H_2\,O = \underbrace{C_{42}\,H_{84}\,N\,P\,O_9}_{\text{Lecithine.}}$$

Lecithine combines with $pt\,Cl_2\,H\,Cl$ and with $Cd\,Cl_2$ like organic bases; but also with oxydes of metals, as silver oxide ($Ag_2\,O$). Its solution in ether-alcohol gives a crystalline precipitate with alcoholic potash solution. It is therefore a base, an acid, and a fat. To prove this by analogies Strecker enters into some theoretical considerations which are of interest, though of subordinate value for the present purpose.

In this research it is rather assumed than proved that the phosphorised body of brain-matter is identical with that from eggs. On the other hand, it is certain that the great bulk of phosphorised bodies from the brain is not identical with lecithine, as their metallo-chlorides observe an entirely different bearing with hydrothion from that which Strecker describes for his lecithine metallo chlorides.

The principal progress in this research of Strecker concerns the introduction as isolating agents of the chlorides of platinum and cadmium; but the details

were insufficiently elaborated, and the cohesion of the parts was rather guessed than proved.

BAEYER. Combination with phosphorowolframic acid does not entirely purify.

BAEYER produced (Ann. Chem. 140, 306), neurine by Liebreich's process, purified it by adding to its hydrochloric acid solution phosphorowolframic acid; the precipitate which fell was washed, and decomposed with baryta water, and the resulting liquid, after removal of the baryta and addition of hydrochloric acid, was evaporated to a syrup. The hydrochlorate of neurine thus obtained is yet coloured, even though by fractional precipitation with phosphorowolframic acid the impurities which fall down with the first precipitates have been removed.

Purify by Pt Cl_4 combination. Three bases.

The best method of purification consists in transforming it into the platinic compound. Several analyses of different preparations led to discordant results, indicating substances of the following formulæ:—

1. $N\,C_5\,H_{14}\,O\,Cl, pt\,Cl_2$
2. $N\,C_5\,H_{12}\,Cl, pt\,Cl_2$
3. $N\,C_5\,H_{14}\,Cl, pt\,Cl_2$

(The small pt indicates an equivalent, = ½ atom of Pt.)

Two bases certain and one problemetical.

A special examination of neurine yielded as a result that it is probably a mixture of two different bases, the platinic compounds of which have the compositions of the above salts 1 and 2. It is questionable whether the third base also occurs in neurine; the analysis of a preparation speaks for the assumption, as also the circumstance that the hydrogen in No. 2 is always found somewhat too high.

Neurine and hydriodic acid.

When a most concentrated solution of neurine hydrochlorate is mixed with several volumes of concentrated hydriodic acid and a little phosphorus and heated in a sealed tube to 120–150° during some hours, then after cooling the tube a considerable quantity of large colourless prismatic crystals is obtained. After recrystallisation from hot water these crystals gave analytical results leading to the formula $NC_5\,H_{13}\,I_2$.

	Found.	Calculated.
C	17·65	17·59
H	3·94	3 81
N	4·10	4·10
I	74·26	74·48

Properties.

Easily soluble in hot water, difficultly soluble in cold, crystallising on cooling in heavy, shining, imperfectly-formed crystals, which are somewhat similar to potassium iodide. From their solution caustic potash precipitates white flakes, which become crystalline. The iodine is contained in this compound in two forms; nitrate of silver precipitates only one iodine from the solution in water, whilst a base containing iodine remains in solution. On long heating, however, the second iodine is also precipitated.

Removal of one atom of iodine by $Ag\,N\,O_3$.

Same with Ag Cl.

Freshly precipitated chloride of silver digested in the cold with the watery solution of the compounds replaces only one iodine by chlorine. The liquid filtered from the silver iodide, on addition of platinic chloride, yields a heavy yellow precipitate, consisting of small octohedric crystals. They are but little soluble in water, and have the formula

$N\,C_5\,H_{13}\,I\,Cl\,pt\,Cl_2$.

	Found.	Calculated.
C	14·4	14·32
H	3·2	3·10
I Cl	56·4	55·08
pt	23·5	23·50

This compound, therefore, contains an iodised base.

Digested warm with freshly precipitated silver oxyde, the iodide loses both atoms of iodine, and yields a base, which treated with hydrochloric acid and

platinic chloride gives a very soluble compound, and in all respects like the neurine compound. On analysis, however, it constantly yields results corresponding to the formula $N_2 C_{10} H_{28} O Cl_2$, $pt_2 Cl_4$.

	Found.	Calculated.
C	19·97	20·00
H	4·49	4·33
pt	32·84 to 32·64	32·83

A. W. Hofmann obtained, by treating a watery or alcoholic solution of trimethylamine with ethylene bromide by a simple combination of both bodies, a substance $N C_5 H_{13} Br_2$. This, by treating with nitrate of silver, loses one bromine, the filtrate gives with $pt Cl_2 = N C_5 H_{13} Br Cl$, $pt Cl_2$, difficultly soluble in cold water; oxyde of silver takes out both atoms of bromine, and the solution is alkaline, and contains neurine. Thus this compound is analogous to the above No. I compound.

Now, whereas neurine treated with hydriodic acid yields the compound $N C_5 H_{13} I_2$, which is really trimethyl-iodoethyl-ammonium iodide $(N (C H_3)_3 (C_2 H_4 I) I$, neurine must be either trimethyl-vinyl-ammonium-oxydehydrate, $(N (C H_3)_3 (C_2 H_3) HO$, or trimethyl-oxethyl-ammonium-oxydehydrate, $N (C H_3)_3 (C_2 H_4 (H O)) H O$. As the analyses of the platinum salts do not agree, it is probable that they are mixtures of both bases, which can yield the combination $N C_5 H_{13} I_2$ either by directly taking up H I or by separating water. Free neurine dissolved in water easily decomposes, yielding trimethylamine. It is therefore to be expected that some of the trimethylamine found in animals and plants during life and after death may be due to a decomposition of neurine.

The group oxethyl also occurs in taurine.

Choline from bile seems identical with one of the bases from neurine.

A. Clauss and C. Kessé on neurine and sinkaline.

The following observations prove that a base derived by decomposition from an ingredient of mustard, sinapine, is identical with the base derived from brain matter. They were made by A. Clauss and C. Kessé. (Journ. pr. Chem. 102 (1867) 24.)

Sinkaline was discovered by Von Babo and Hirschbrunn (Ann. Chem. 84, 10) as a product of decomposition of sinapine. This base the authors only saw, as prepared by the discoverers, but did not themselves prepare it. They made, however, a quantity of neurine.

The brain, after being stirred and comminuted with water, was extracted with a mixture of about equal volumes of alcohol and ether, because it was found that this solvent separated quicker from the brain matter after stirring with water than pure ether, and further, because they believe that ether alone yields ultimately less neurine (*i.e.*, dissolves less myeline and lecithin). The alcoholo-ethereal extract was immediately mixed with concentrated baryta water, and distilled during 24 hours. This process yielded more neurine from eight calves brains than Dybkowsky's process from 18. The watery solution was then treated with carbonic acid, the filtrate evaporated to a syrup, the latter exhausted with alcohol; the alcoholic solution was acidified with hydrochloric acid, and mixed with alcoholic solution of platinum chloride. A copious yellow precipitate fell in cheesy lumps. (The addition of ether to the mother liquor causes a further precipitate according to Dybkowsky, but according to the authors this (ether produced, Th.) precipitate contains little or nothing of the neurine compound). The precipitate is almost completely soluble in water and on slow evaporation of the water a mass is obtained which is more or less crystalline, and seems essentially to consist of three different substances. The platinic salt of neurine is present in quantity, and is separated from the two other bodies by fractional solution, one body being easily soluble in cold water, the other almost insoluble in it (so that platinic neurine seems to have an intermediate solubility, Th.).

The body nearly insoluble in cold water dissolves in water on long boiling, and is again deposited on cooling. Though it contains carbon, visible on combustion, the authors suspect it to be potassium or ammonium platinic chloride.

The neurine-platinic chloride dissolves in cold water, but not easily, quickly however in warm water, and is obtained from the solution in different forms. On cooling a hot saturated solution small needles are at first deposited; on evaporating the mother liquor over sulphuric acid thick columnar crystals are formed, and ultimately on exsiccation a mass of confused crystals is obtained which resembles nitrate of urea. If a small quantity of free platinic chloride be added to the solution rhombic prisms are formed.

The auric chloride of neurine (and sinkaline) crystallises from hot water on cooling in yellow needles, later on in yellow scales. On heating the salt the smell of trimethylamine is observed.

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